TELESCOPE MAKING 26

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The magazine *for*, *by*, and *about* telescope makers!

Summer 1985

TELESCOPE MAKING

The magazine *for, by,* and *about* telescope makers!

Editor: Richard Berry

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Editorial

Well, here's another TM at long last, only about four months behind schedule. I hope that not *too* many of TM's readers have given up hope of ever seeing another issue of TM. We are still publishing, albeit slowly.

Why is this hapening? Those of you who read ASTRONOMY will probably remember that in the March 1985 issue we announced that Kalmbach Publishing Co., a Milwaukee-based publisher, was going to purchase AstroMedia Corp., the company that publishes TM, among other things. Well, the sale finally went through on August 1, 1985. In the two months before the sale and in the time between then and now, my time has hardly been my own. In addition to my new "corporate" duties, I'm still trying to get ASTRONOMY out there to meet the enormous market created by Comet Halley. Our 144-page October issue, for example, and the 112- and 116-page issues following and preceding it, have taken considerably more than the normal quota of time and energy.

So much for my tale of woe. This is the special Dobsonian issue of TM, an attempt to fill you in on recent alt-az technology and to leave space for a wider range of topics in upcoming issues of TM. Special thanks go to the people who helped get this issue out, especially Pat LaBrecque who keylined many of the stories in this issue. Meanwhile Susan Ryan, an Editorial Assistant for ASTRONOMY, has already started working on some stuff for the next issue, so maybe we'll manage to do another TM before too long. . . .

Richard

Letters

Ain't Much I'm Askin'

Dear Richard / Just a note to say that TM#25 ain't much. The article on the eye needed captions on the illustrations, didn't need a full-page diagram of the eye that had no bearing on the article, and didn't need to be included in the issue at all as it didn't deal with telescope making.

The 15-page article on eyepieces looked interesting, but was a total bust. Again, you filled space with an unrelated diagram of the eye. The diagrams and graphs were nice — if the reader were an optician. But what about those readers unfamiliar with the terms used? Why not a translation or interpretation of what the curves mean? Why not keep the scales the same for the various distortion curves? It appears that the "op distortion" and "focus" scales change from chart to chart, and the legends are so small and the printing so lousy, that you can't read them. I was expecting some useful information from the article. All I got was some ivory tower dither.

You should have Buchroeder read Venrooij's review on the Nagler in TM#20, and then write for people instead of other Ph.D's before he does another article for you. Also, put more articles on telescope making into "Telescope Making."

Fred Bieler
Ad-Libs, Incorporated
2401 Tee Circle, Suite 10
Norman, Oklahoma 73069

— Thanks, Fred, for your outspoken comments. I agree that TM#25 has a hastily thrown-together appearance because, in all honesty, it was hastily thrown together. As implied in the Editorial, this happened because my other duties here at AstroMedia (now a division of Kalmbach Publishing Co.) come first, as they always have and always will. That is, like it or not, an inescapable fact of life for this little magazine.

Buchroeder's article, I believe, is defensible because because it sets out to do a broad comparison of many eyepiece types, rather than an in-depth analysis of a single design, as Venrooij and Rutten did. We did ask for sharper graphics, but the computer-plotted originals were no longer available. I agree that a common scale would have been nice, but the program apparently auto-scales the data for each plot. Too bad. It would have been nice to have all the terms carefully defined, but I tend to assume that TM readers know more about optics than the readers of either ASTRONOMY or Sky & Telescope, *or are more motivated, and will look up any mysterious terms in a book on basic optics.*

As for your final point: TM draws on its readers as authors. By myself, I can't "put" more on telescope making into this magazine. That's your role. There seems to be a trend toward sending TM more "theoretical" articles, and I assume that if that's what you folks are writing about, that's what you're thinking about, and therefore, what you're interested in. I would urge you, and others who feel as you do, to write articles about making telescopes if that's what you want to see in TM. Don't "let George do it." Remember, Fred, as a reader, you are also a TM author, even if it's only by merit of what you don't write.

— RLB

Super Eyepieces Coming!

Dear Sir/ Prototypes of two new eyepieces were demonstrated at Riverside and Stellafane this year. Both, like the famous Nagler design, employ an integrated negative amplifier to acheive a truly flat field with outstanding performance even at very fast f/ratios. With the exception of distortion, which remains high in all such designs to date, these designs demonstrate that previously insurmountable eyepiece problems have at last been resolved.

One of the new designs is able to eliminate the coma of a parabolic primary mirror of any size or speed, and to alleviate the coma of some Schmidt-Cassegrains. The resulting performance is truly phenomenal and seems likely to set new standards for the next generation of quality eyepieces.

Unfortunately, such eyepieces are bigger and more complex than conventional ones, and will therefore tend to be more costly. Cost is particularly related to the field of view, which affects the number and size of elements required. For a fast Newtonian, it is easy to see that the new coma-correcting design is superior to conventional ones even over a small field of view.

The non-coma-compensating design introduces no faults of its own into the image

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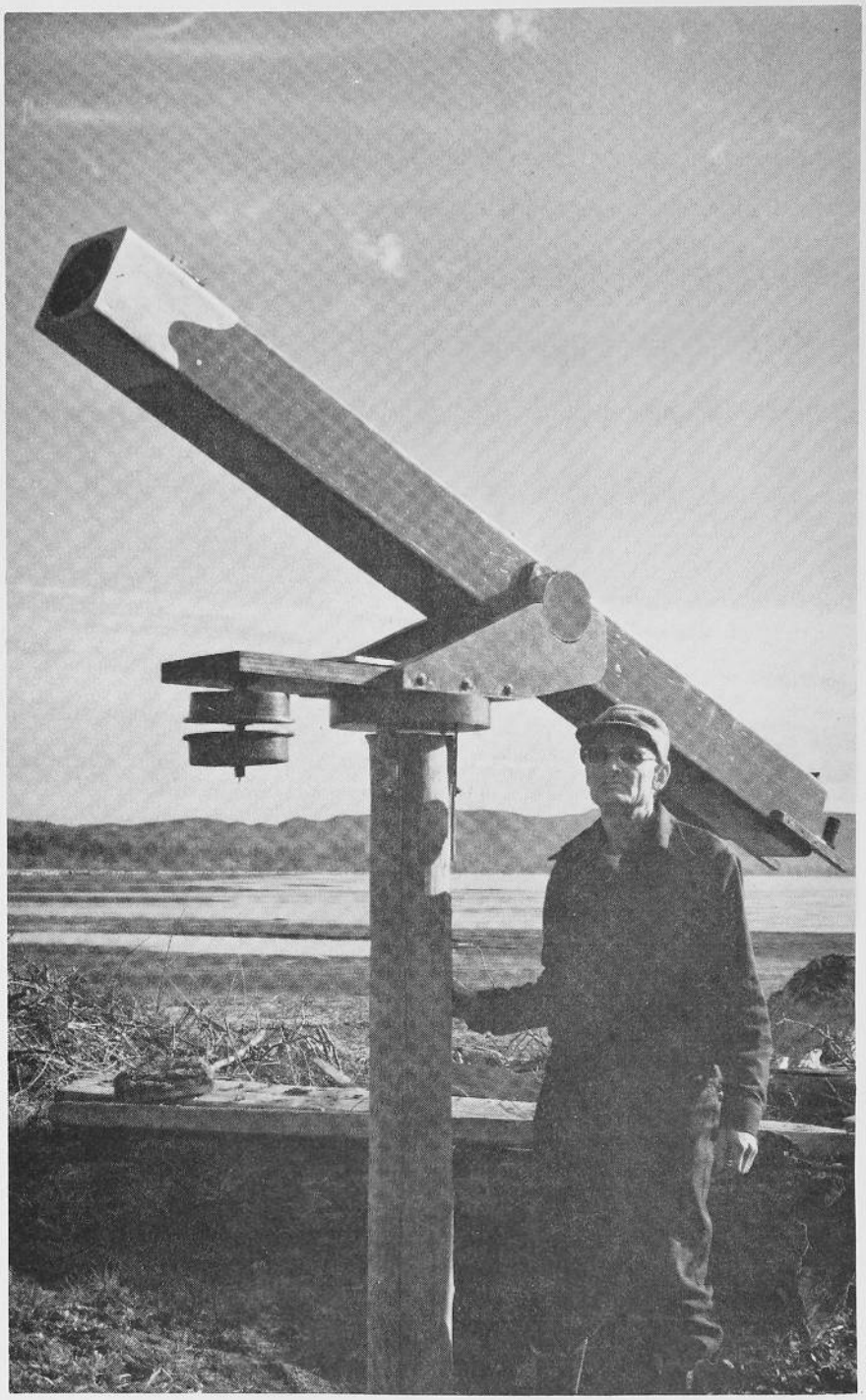
Sharing Dobsonian Technology

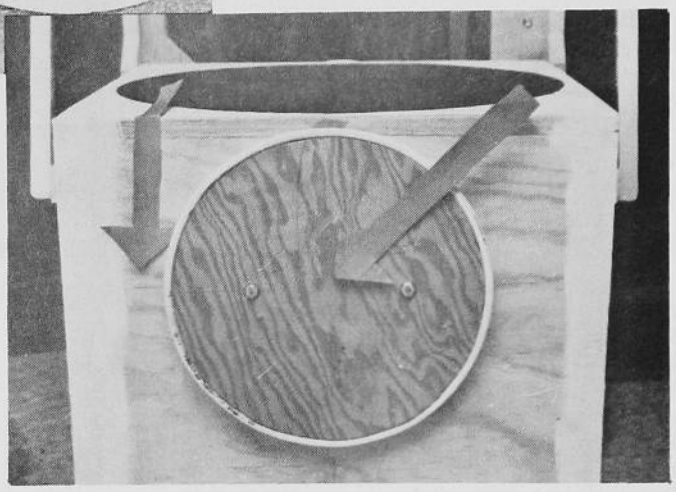


Dobsonian Refractor on Permanent Pier

For my permanent observing site, I recently completed a 6-inch refractor with a Dobsonian mount atop a permanent pier. The instrument has a commercial objective. The photo shows most of the important details — you will notice I borrowed heavily from the instrument shown on the cover of TM#19.

Jay Hardin
Star Route
Ilwaco, WA 98624

■



Pail Rims Make Good Side Bearings

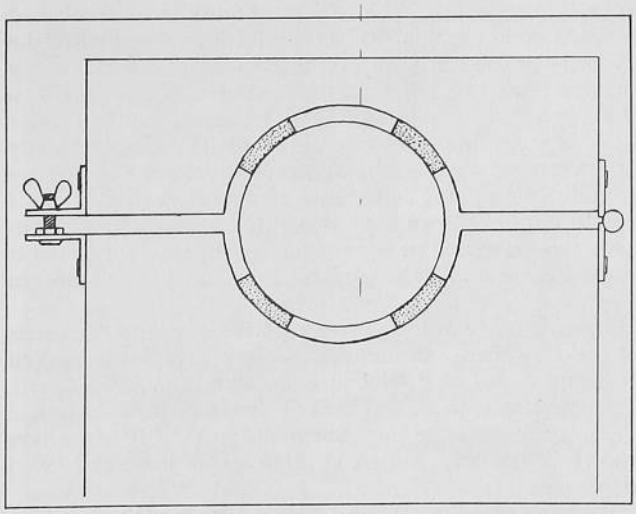
Plastic pail rims — those big plastic pails you see filled with pickles in delicatessens — make pretty good Dobsonian altitude bearings. I used them for my new 17½" Dobsonian. I used two different pails. One has an inside diameter, at the pail top, of $11\frac{3}{16}$", and an outside diameter of $11\frac{15}{16}$". The other pail has an inside diameter of $11\frac{3}{8}$" and an outside diameter of 11½."

Not only does the plastic work well on Teflon, but the rims on the pail help center the mirror box onto the cradle. I removed the pail's wire handle and used a table saw to cut off the rim evenly. The saw in the photo was used to help ruin the first pail I tried. I didn't glue on my bearings — but used bolts. If I ever have to, I can move them to re-balance the scope.

My pails originally held blacktop covering material, but bakery grease pails and pickle pails are just the same. To get them, you only have to "beat the truck on pickup morning." Smaller pails are often available if you want a bearing smaller than 12".

Mike Priesbe
314 Arrowhead Dr.
Shorewood, IL 60435

■



Friction Control

Several years ago I built Dobsonian mountings for my 6-inch and 8-inch telescopes, and I have enjoyed using them ever since. However, one shortcoming of my mounts was too little friction in the altitude bearings. There are many times when being able to control it would have been desirable. For instance, when I'm using a particularly heavy 2-inch eyepiece which throws off the balance of the tube, or I when I want to give the scope more resistance in a stiff wind, or when I want to hold it rock-solid for photography, I'd like to turn a knob and make it sit still.

The sketch shows the little device I created to solve this problem. It is simply a piece of wood attached to the top of one side board with a hinge and clamp. A semi-circle is cut out of it and two Teflon pads are mounted inside so that the altitude bearing is now enclosed on four sides with Teflon. The little L-shaped metal pieces that support the wing nut are common fasteners found in almost any hardware store. When the wing nut is loose, the telescope turns as if the top piece is not even there. As the wing nut is tightened though, pressure is applied to the altitude bearing until the scope becomes quite rigid. Incredibly, even when the bearing is clamped down full strength, it's possible to move the scope if you want to. It just takes a good shove!

This altitude friction control has much to commend it: it's easy to build, it can be retro-fitted to existing telescopes, and it works!

Ralph Bernstein
1300 Lake Shore Dr.
Chicago, IL 60610

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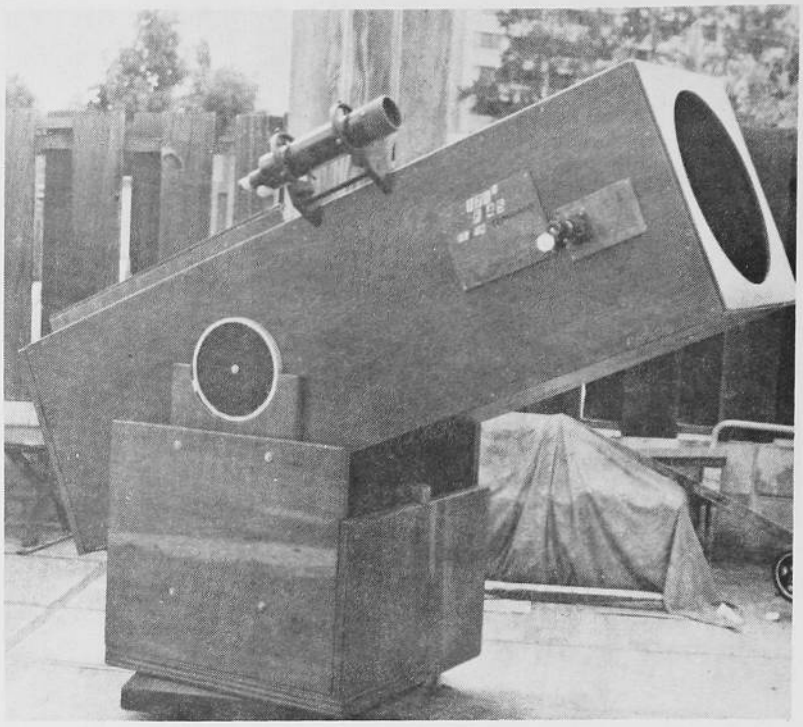
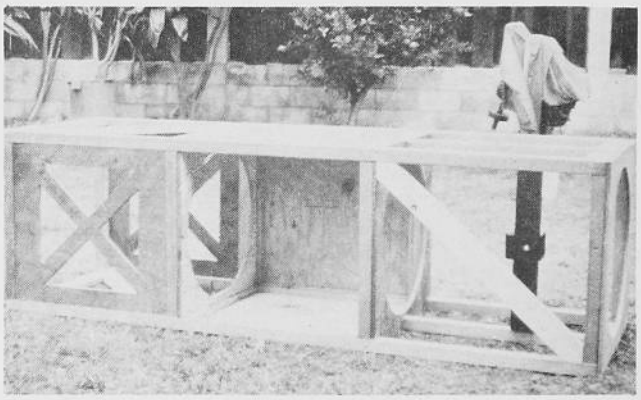


Square *versus* Round Dobsonians

The old saying that there's nothing better than a good little telescope except a good big telescope underlies the whole Dobsonian revolution, but I'll get to that later. For the time being, I'm going to tell you about the convenience of a "box"-type Dobsonian for "hangin' things onto," compared to the difficulty of doing the same with a conventional round tube. Everybody needs to mount secondary and spotter scopes, chart holders, plaques, etc. — with a square tube, they're all just nailed on as needed.

Weight problems are handled with equal ease. I've been known to hang a common hammer on the rear of my 13.1" out in the field. Why? I found out, the hard way, just how much a Nagler eyepiece weighs. A screw located at the rear of the scope accommodates the claw of any hammer nicely, and will also work for string with a rock hanging from the end of it!



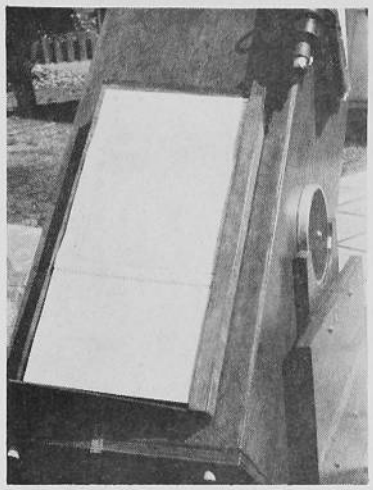
Back to the subject at hand. As you know, I track asteroids. But I also do planetary drawings of Mars and Jupiter for ALPO. For both purposes I use a homemade 17.5" Dobsonian patterned after Richard Berry's 20" in TM#7. As you might expect, changing filters and using different adaptors depending on the type of eyepiece used, as well as other factors, all act to slow down the process of planetary drawing. So, on an impulse, I made a filter wheel. As you can see from the pictures, it's not anything special. Indeed, if I had taken the time, I'm sure that I could have come up with something a little better, but the point here is that it works and, I might add, it works very well. The knob that controls the filter positions is located near the eyepiece, so in a matter of seconds I can go through the entire range picking the best filter for the conditions of the moment. What a time saver! No fumbling in the dark, no lost parts and, best of all, no ulcers.

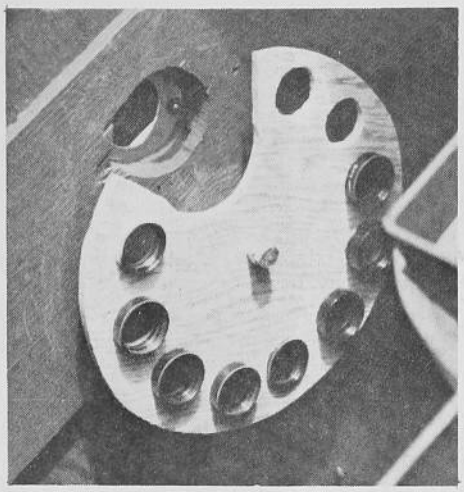
That's about it for my pitch on the advantages of a "box" scope. I've included a few photos which should be self-explanatory. As you can see, I keep a record of my asteroid observations on the side of the scope as well as comets observed. These are hand-printed in black enamel and overcoated with Varathane. I'm up to 805 now and moving in on the magic number of 1,000 at a rapid rate.

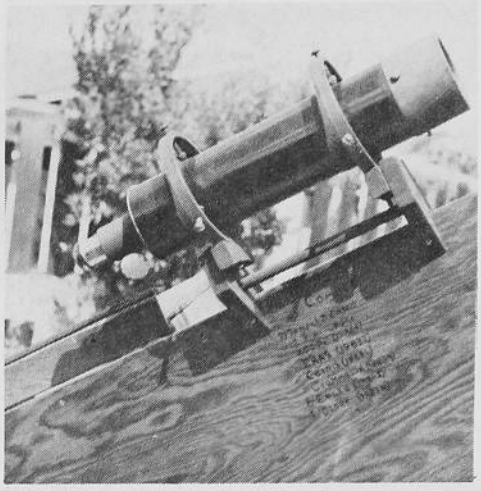
Some thoughts for the anti-Dobsonian people. Talk about benefit versus cost: when I brought my 17.5" on line, I gained the distinction of owning the largest telescope on the island of Oahu for under $750. And the old saying that there is nothing better than a good little telescope except a good big telescope (which I realize I said before and I'm happy to say again) is really true here. First of all, I don't track asteroids entirely for myself. Some important work is accomplished here. Asteroid trackers, by and large, simply confirm that the majority of asteroids are where they should be, but every once in a while we come across a couple that are off by a good amount and thus alert the professionals to take a closer look. We also find gross magnitude errors and occasionally detect rotational periods as well as occultations. I could have continued observing asteroids with a good quality 8", but I would not have been able to see due to the limited light-gathering power of an 8". For the money, the only answer was a large aperture Dobsonian. Thus the 17.5" and interim 13.1".

The final say, however, comes at star party time. Members of the Hawaiian Astronomical Society have seen the Veil Nebula . . . all of it. Not just the section near 52 Cygni. They've also seen a good deal of the Horsehead Nebula!!! True, conditions were ideal, but would an 11" f/10 scope have shown it? Possibly. But an 11" f/10 scope that cost $750? I think not.

We have gazed in awe at a distant 12th magnitude comet







and pondered over the H-II regions in M-33! Oops! I forgot. Add $200 to the cost — because we have seen all these things with a Nagler. Are the images acceptable? Yes — and I'm a planetary observer. And judging from all the "ahhhh's" I hear at our star parties, I'd say that they are very acceptable images indeed.

Well, I guess I'll get off my soap box now. May I just end by adding that the planetary images with the 17.5" at full aperture, when seeing conditions permit, are outstanding. Coulter is doing a fine job on quality control. I'm proud to be a Dobsonian owner.

Ray Fabre
President
Hawaiian Astronomical Society
99-066 Ohiaku Pl.
Aisa, HI 96701

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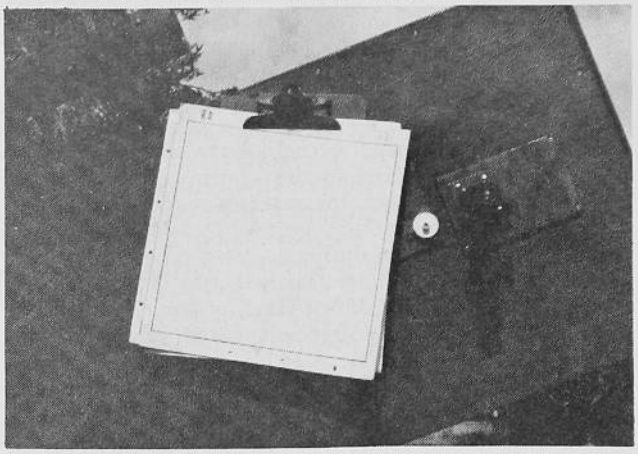
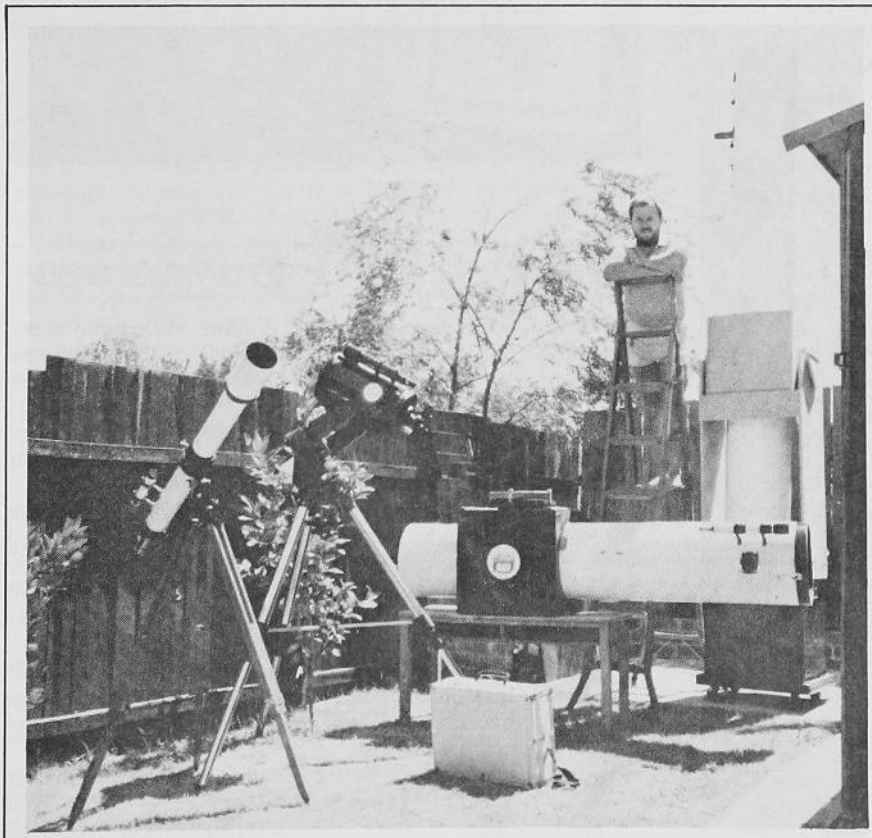




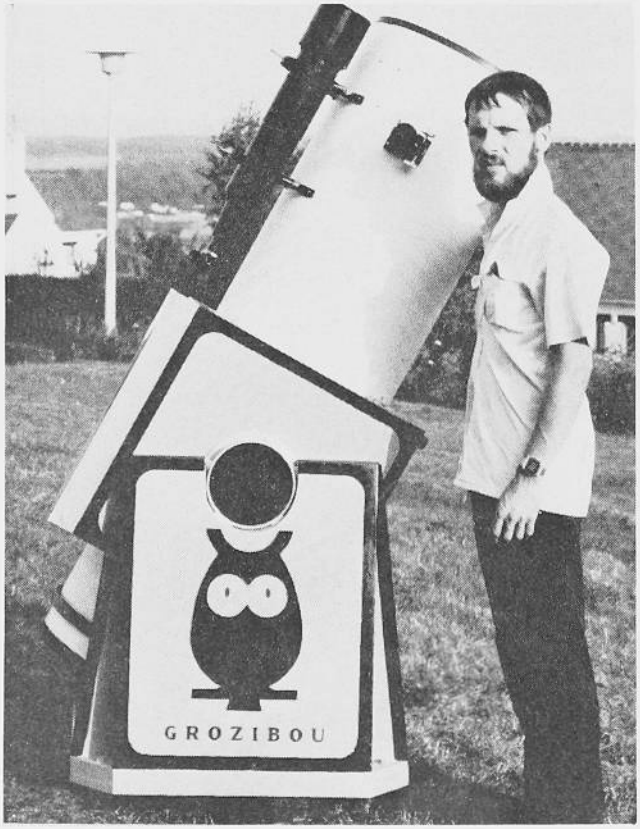
Grozibou: a French Dobsonian

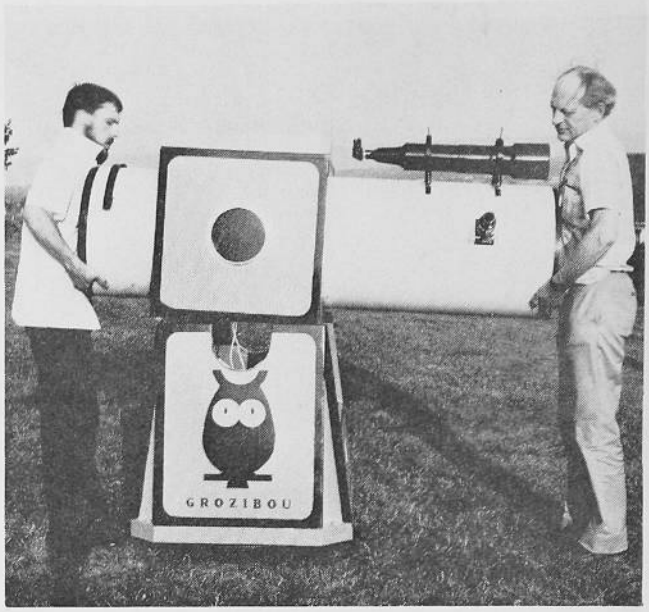
I am sending some photos of my Dobsonian telescope "Grozibou" to illustrate an article for TM. Enclosed also is "Pulsar" in which I write about my Dobsonian. Perhaps your readers will learn French.

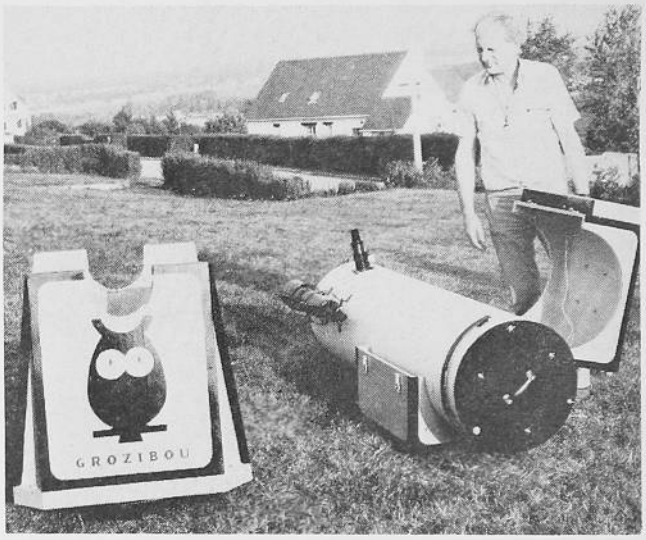
At the end, I think I have a good topic for *Deep Sky*: the observation of the NGC-68 group, which ranges from 14.5 to 16 according to the RNGC. The group is near r.a. 0h 17′ 1″ and dec. 29° 56′ (1975), just east of Alpha Pegasi. At 90x we see only a faint patch of nebulosity with three 13th magnitude stars involved in the system. No individual galaxies are seen. At 180x, the patch is better defined. We can see it is round, but nothing else. More power is not useful.

I tried this observation during a very good night (for my observation site) last October. (That night M-33 showed a lot of nebulosities at 90x and 180x.) Timothy Ferris, in his book *Galaxies*, has published a fantastic photo from Palomar (photo 128).

Jean-Baptiste Cretaux
4, rue Grande
27430 Saint-Pierre
du Vauvray, France ■







The Delrin-AF Advantage

I have been using Delrin-AF (Teflon loaded) to make binocular trunnions. This material is much easier to machine than Teflon. Mate it with UHMW or Teflon bushings, and run the bearings dry.

The major drawback of Delrin-AF is its cost. It costs about the same as Teflon, or about three times the normal cost of Delrin(R).

I've noticed that UHMW samples exposed to UV outdoors for six months have developed surface crazing and they cracked partially when bent. This may not be a problem for scopes since no effect was seen in the first two months, and most optical instruments don't receive continuous outdoor exposure.

UHMW is as flexible as Teflon, making it difficult to machine. Aluminum C-collets, made to size and then sawn parallel to the axis once, help hold flexible stock for boring thin wall bushings.

Gordon Rayner
Box 1742
San Diego, CA 92112 ■

Success Story

I currently own five telescopes including a C8, but setting up the dad-blasted thing in the dark was running up my hardware store bill. I happened upon a very nice 8-inch f/6 mirror one day and squirreled it away for a "rainy day," with visions of a nice aluminum photoequatorial dancing in the back of my head. I had also accumulated some scraps of Sonotube from a friend's basement, and the whole lot sat around until the day we got snowed-in a couple of Februarys ago. In your neck of the woods, snow is at worst a nuisance, but here in Washington, D.C., 17 inches of snow turns off the city for a week. Well, my "rainy day" had arrived, although the rain was a little on the white and puffy side, and I decided that it was time to build my first telescope.

I decided to go with the Dobsonian layout because, while the vision of a photoequatorial still danced in my head, I also had a strange urge to show my friends that a good astronomical telescope could be built for a low cost. I put on public stargazing programs for the local park authorities here, and I was getting tired of people sidling up to my C8 asking, "How much that sucker setcha back?"

"Well, uh, (cough, cough), oh, 'bout a grand or so..."

"Yer kiddin'!!" etcetera, etc.

I wanted people to see a nice image of Saturn or the Lagoon Nebula for around $200.

Being inherently lazy, I pored over the Novak catalog and phoned in my order for the mirror cell, diagonal, holder, spider, and focuser. I had some aluminum shelf-bracket runners that I was going to use in the downstairs bathroom (my patient wife is still waiting for the rainy day when I start that one!), but the Sonotube scraps and the runners cried out for each other and the telescope was born.

The tube went together off the top of my head. I decided to use six runners spaced 60 degrees apart to hold the two sections of Sonotube apart. At the time I didn't realize that this was going to save me all sorts of hassles when it came time to attach the alitude bearings; I just wanted to get the optics together to get a first peek. 8-32 hardware with oversize washers holds everything together and so far hasn't required any adjustments.

The unofficial date of first light was March 13, 1983, with the tube propped up on a cinder block in my backyard. I slid the head piece with the secondary and eyepiece assemblies into the open ends of the runners and focused on Mintaka. Darned if it didn't split that close double! I clamped everything together and hurried to look at the Great Nebula, where the E and F stars in the Trapezium jumped out at me. The next night I had the works bolted together and, with my trusty cinder block mounting, proceeded to blow my C8 out of the sky.

A more elegant mounting was the natural next step, so I drew up some plans (which I have not managed to lose yet) and headed off to the lumber yard. One 2x4-foot sheet of ¾" plywood, some donated Teflon and Formica, and one weekend went into the mount. Then I realized that the telescope had to sit on the mounting, so I went back to the hardware store for two PVC closet flanges. The counter clerk asked me how many bathrooms were in my house, but when I told him I was building a telescope, he walked away muttering something about Saint Elizabeth's and out-patients . . .

The flanges were attached to the tube with some pieces of scrap ⅛" aluminum stock which I had to bend in a brake, and I only missed the balance point of the tube by ¼"! This was easily corrected by bolting on my old C8's finder and one Celestron counterweight.

Official "first light" came on March 23, 1983 after a lecture in the Planetarium by Gerald Hawkins, when a group of about 50 people stopped by to view the Moon and Saturn. Since that time, well over 1000 people have viewed the wonders of the Universe through this trusty 8-inch.

I can't tell you how much I have been enjoying the telescope and how dusty the ol' C8 is getting. I am now embarked upon a self-guided tour of the Herschel Catalog. After only twelve evenings in the country, I'm up to 277 objects. I find that star-hopping with my dinky finder, gliding along on Teflon bearings, is far easier than using setting circles. I find twice as many objects as my friends with SCTs in the same time interval; I just whip out a chart from *Atlas 2000* and start picking things off right and left — which works well until I get into the Virgo Cluster where there are lots more galaxies than the charts indicate! According to the RNGC I'm hitting some that are as faint as 14.5. My best effort to date has been the detection of NGC-7335, a companion to 7331 in Pegasus. I'm also doing well on wide-field objects, having had some wonderful glimpses of wisps in the Veil Nebula, structure in the Helix, and spiral structure in M-33.

In summation, I'm proud to have built my telescope! Even though a "purist" might say I cheated, I know I created a fine instrument with my own hands. The point is that anyone can and should do it, and they don't have to think big, either. From most near-urban areas, an 8-inch will do as well as a 12-inch, and it's easier to lug around to boot.

I've been enjoying TM for over a year now and the only advice I can offer is keep up the good work. Your contributors are certainly very industrious and inspire the likes of me to take up the challenge of telescope construction. Although my project is not as elaborate as many that you've showcased, I decided I'd put in my nickel's worth anyhow. TM does a great service for amateur astronomy, and an issue on Dobsonians ought to be well worth the effort. I've certainly rediscovered the joy of observing with mine.

Geoffrey R. Chester
NASM 3356
Smithsonian Institution
Washington, DC 20560

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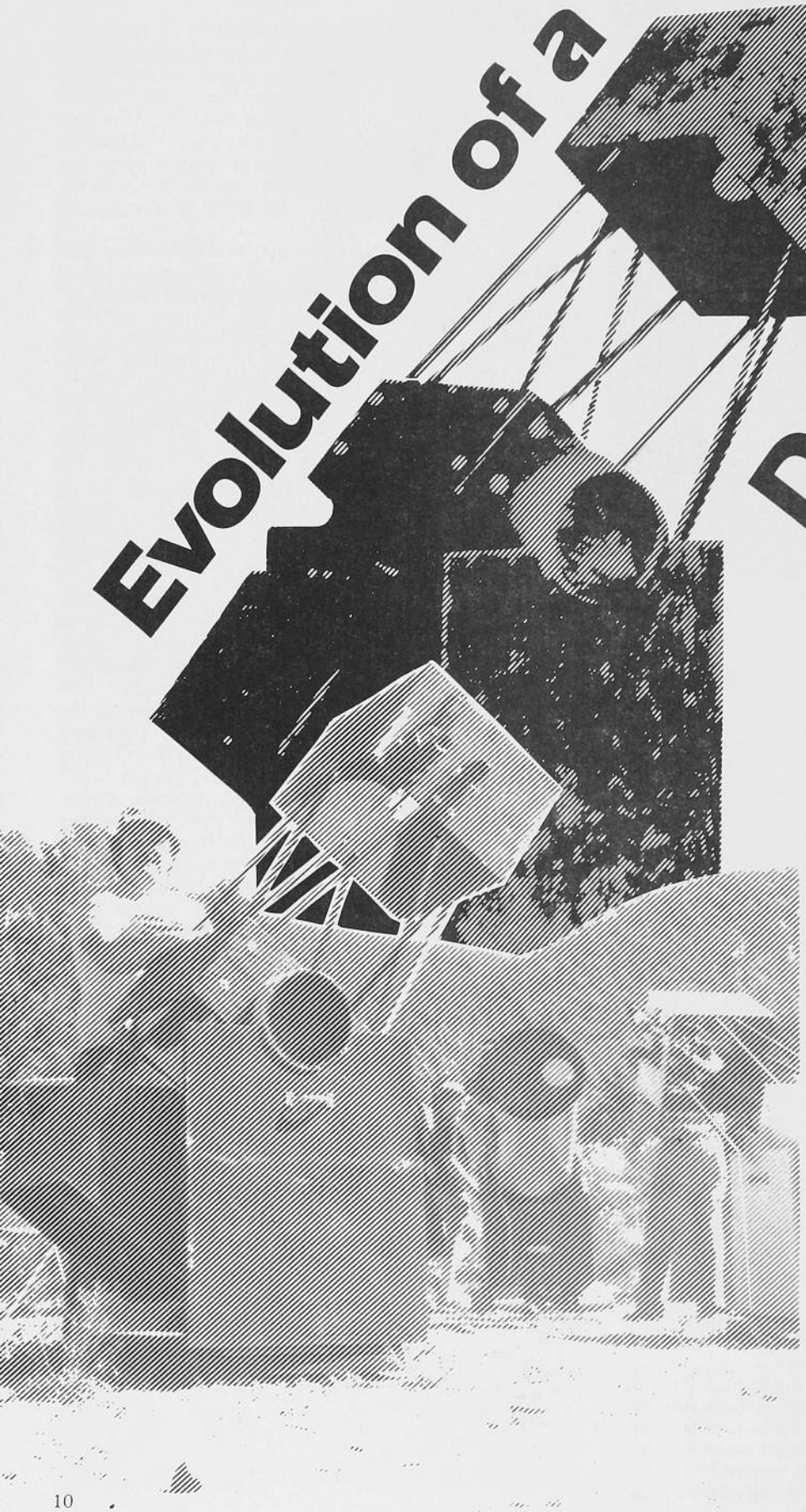
Evolution of a Dobsonian



I took delivery of my 17.5-inch f/4.5 mirror from Joe Neu of Coulter Optics at the 1980 Riverside Conference. In the four years since, the telescope holding this mirror has been in three different forms. I would like to share with you its evolution to my present scope — and why I think it is better than its previous styles.

If you hope to wind up with a transportable large telescope, then there are several variables you must consider. The first of these is what transportion you intend to use to move the Bedouin Leviathan. A flat-bed truck with a power winch is handy but very expensive. Although a Volkswagen was once cheap transportation (though not any more), the only way to get the scope inside a Volkswagen is to remove the seats and gas tank.

I finally narrowed the choice to a van or small truck. A quick glance at the price of a van had me driving my old jalopy to the local dealer to look at trucks. As the salesman approached, I was in the bed of a truck with a tape measure.

He said, "Hi, what are you doing?"

I said, "I'm seeing whether my telescope will fit."

When we went inside to sign the papers, I heard him whisper to a friend, "This is the guy."

Once you've got some means of

getting the scope out to the observing site, you can start thinking about construction. I highly recommend the TM reprint booklet, "How to Make a Dobsonian Telescope." There are a variety of designs in the booklet — and you can see how many other people have solved the same problems. When I was getting started, the only designs I had seen in person were at Riverside. No one else in my area owned a Dobsonian telescope, so my first Dobsonian was a traditional design with a Sonotube within a plywood box.

That Sonotube distributor in Phoenix must be the father of 100 scopes. He knows that a single order for a short length of Sonotube must be an ATM starting a project. When I arrived to pick up a 7-foot length of 20-inch ID tubing, he was very impressed. I was impressed, too, by the fact that it barely fit in my new truck. I immediately started recalculating the focal length, but there was no mistake. Seven feet looks bigger than it sounds.

A lot has been written about getting the wax coating off a piece of Sonotube. I found it was very easy to do. I set the tubing out in the Arizona summer Sun for three days and the outer coating was gone. The inner coating peeled off in five minutes — then it was time to paint the inside of the tube. I chose flat black paint in spray cans. It seemed easy, but crawling into a large tube can be very uncomfortable. Once the fumes from the paint get back to you, though, you'll forget any cramps. You'll also forget your name.

So I started assembly of the box that contains the tubing. The inside width of the box must equal the outside diameter of the Sonotube. You want it to fit snugly; any wiggle will affect collimation. It ought to take some muscle to get the box over the tube — but mine was *real tight*. My friends and I wound up setting the tube and box assembly upright and pounding the box over the tube from the roof of my house. Several of my neighbors were prepared to testify if my wife tried to have me put into a home for delinquent astronomers. After all that effort, I still put four ¼-inch bolts through the box and tube so it wouldn't fall out . . . just in case. A team of Clydesdales couldn't have pulled that tube out of the box.

My next step was making the mirror cell and tailgate assembly. Thin mirrors demand nine-point suspension; I made my triangles out of ¾-inch plywood. The rubber pads at each contact point of the mirror are faucet washers, hard rubber molded into a truncated cone shape. They have held up very well over several years of hard use. The sling that supports the mirror at the edge is

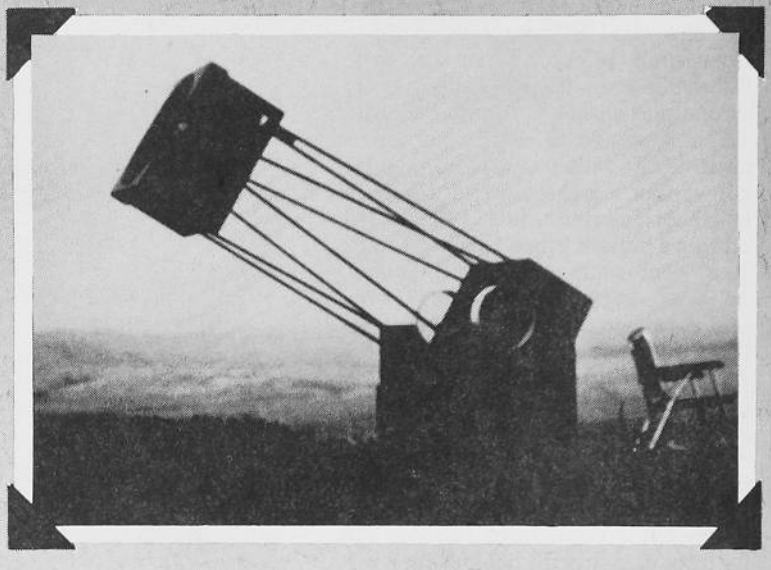
The scope in its present form, with three boxes - upper, lower and trunnion - connected by 3/4 inch square steel tubing.

Set up at Texas Star Party 1983

another Texas

Set up near Mt. Hopkins, where the MMT lives.

Style #2: two boxes and long struts. Very shaky. The scope was together this way for only two viewing sessions. I learn fast.



The dance of the astronomers. David and I remove the box from the Sonotube by delicate surgery.

Sliding the box over the tube for Style #1. My landlord, Gary Ellingham, took the shot. He said something about useful evidence at my hearing.

a piece of seatbelt I found at a hiking supply store. Hikers use them to make waist and shoulder straps for packs. After carefully centering the mirror on the tailgate and seating the sling so that it supports it dead center, I nailed the tailgate in place at the center of the rear opening of the box. I then put a long piece of piano hinge all along the bottom of the tailgate and box. A long hinge will make certain the tailgate doesn't wiggle.

I used two-inch-long wood screws and Titebond glue for all the assembly on the telescope. This is probably tremendously overdone, but I've never had any problems with parts separating. Once the tube is in place, you need to figure out where to drill the holes for the spider. I missed. I have never determined whether my calculations were wrong or a measurement was off, but I wound up having to elongate the hole for the focuser and redrill the spider holes. Maybe the focal length etched on the side of the mirror was wrong. I don't know. (It is tempting — and easier — to blame Coulter than believe I was wrong.) Anyway, I covered the extra holes with a piece of black cardboard. Some people believe it's a light shield for the focuser, but now all of you know better.

Next, it was time to come up with a diagonal mirror holder for that giant 4.25-inch minor axis secondary. I couldn't afford such a large commercial unit, but I remembered an article by Pierre Schwaar in Tucson. He used RTV rubber cement to glue a 16-inch mirror in place. I used RTV to glue the diagonal to a 3.1-inch secondary holder I bought from a friend. Three years later, when I wanted to remove the mirror for realuminizing, I found out how good a bond RTV makes. I wound up using a two-pound hand sledge and a chisel. I had to literally pound the diagonal loose from the holder. A couple of friends who were visiting at the time had to turn their backs because they couldn't bear to look . . . so they said. Maybe they were just looking up the price of a new diagonal.

After the main optical tube assembly is done, you determine the point of balance. Put the scope together with all the components in place. Don't forget the finder scope and your heaviest eyepiece. Rather than trust a calculation, I decided to balance the telescope to see for myself where to attach the side bearings. So I acquired a test device for this purpose, commonly known as a broom stick. Once the scope balanced, I marked the side of the box and attached the 10-inch PVC pipe to the box. The bearings were held in place with wood screws in countersunk holes drilled through the PVC.

At this point I decided to take the tube assembly outside and see if it would focus on an astronomical object. Of course, the test object was the Full Moon, because that is what's up when the best scopes are made. Picture this: We prop the scope against a chair and aim it at the Moon as best we can. Dave Fredericksen is helping me. He's at the eyepiece while I push and shove the scope to aim it at the Moon. Dave says he can see a glow so we must be close. When I give another thump and bump to the scope, Dave's face lights up like a flashbulb. He immediately covers his eye as if he had been poked with a stick. I assume we have found the Moon and ask if it is in focus. Dave says something about my parents.

These 17-inch mirrors really collect a lot of light.

After the tube assembly was complete, it was time to start the cradle and ground board. I used double thickness ¾-inch plywood for most of this part of the scope. I waited to determine the height of the side bearings before starting to cut wood for the side boards of the cradle box. I realize that may seem cowardly, but it's a lot easier than winding up with a large supply of scrap plywood. To make the double thickness boards, screw and glue them together and place everything heavy you have in the house on top of the boards. I used an orange telescope (in a truck) for weight. Just backed it on. An old weight set of yours which is rusting in a storage shed can finally come in handy.

I discovered several tips about the Formica-on-Teflon bearings that can save you some grief. Even though it seems silly, don't use the smooth Formica. Smooth Formica allows dust and small pebbles to imbed in the surface and the movement becomes jerky. Try to get Formica with a slightly grainy or stippled texture. This works better and lasts longer. Make the bottom bearing as large as your piece of Formica will allow. Set the Teflon pads away from the central bolt as far as possible. Also, don't put the bolt dead center. It should be offset an inch or so toward the front of the scope. I found this keeps the cradle box from rocking back and forth on the Teflon pads.

Make certain that you sink the nail heads deep into the Teflon pads or they'll scrape the bearing material. Maintaining the Teflon is easy: scrape it occasionally with a sharp knife to remove dirt imbedded in the pads. Don't try any additives. I know several people who have tried a variety of compounds on Teflon bearings with no success. The positioning of the pads on the side bearings will determine the

If a hammer is not enough, try a size 10.

Set up in the Arizona desert, ready for a good night. My wife calls this shot: "A boy and his Taf."

push pressure of the scope in altitude. Try to make it match the push pressure in azimuth as closely as possible. It's easier to follow an object when the push pressures are equal.

When the scope is assembled, it's time to put a finish on the wood. Here is where I made a critical error — I believed the appearance of the little piece of wood in the hardware store. It showed how the finished piece would look with the stain. The stain was called "Norwegian Gold." Honest. When I was done, however, it looked like "Hot Dog Mustard" to me. I did do one thing right, however: I coated the entire telescope in Thompson's Water Seal. This sealer is easy to apply and does a fine job. In all these years of dew and occasional rain, the plywood has not split or cracked.

Okay, that's Phase 1 of my construction story. The instrument stayed in the traditional Dobsonian form for over three years. This style has several positive aspects. Most important, it is easy to construct. With two helpers, I did the whole job in just two weekends. If you want a quick method of getting a scope up and working, this is the way to go. The large mass and double thickness wood construction make a rock-steady mounting. It is reassuring to be able to focus at 200x with little or no wiggle.

However, like most simple things, it has its drawbacks. The weight of the tube assembly *without* the mirror is 110 pounds — and it's all one piece, making it very awkward for one person to set up. Even though I did occasionally set it up single-handed, the price was 30 minutes of hot and sweaty work. Fortunately, finding somebody to help set up a 17½-incher under our clear Arizona skies is easy enough — usually one phone call does it if you promise to let them look.

The other problem is the fact that the mirror must be removed for transport. This subjects the mirror surface to fingerprints and dirt which will surely shorten the life of the coating. After only three years, my mirror is ready for another mirror coating and I've been as careful as reasonably possible. Furthermore, removing the mirror with every use means you're going to get very good at collimating Newtonian telescopes, or grow to like comatic star images. Again, a friend can help a lot for quick collimation.

I also found that a 35-pound piece of glass assumes weird shapes as it cools. The long tube doesn't allow warm air to escape efficiently. Paul Maxson and I decided to try the cool, crisp air near Flagstaff on a September Saturday night. We left 105-degree hot Phoenix and

arrived at an observing site near Flagstaff with the temperature a chilly 45 degrees at sunset. The still-hot mirror didn't even have a focal point for the first 30 minutes. After that, it looked like the star images were swimming in Jello. Two hours passed before the scope was performing well.

With all those problems in mind, I decided to try some different designs that would allow easier set-up, promote faster cool-down, and keep my grubby hands off the mirror. I immediately thought of the open tube Serrurier truss — very trendy — but my first attempt at Phase 2 was very unstable. To get the pieces off the tube, I had to jump on them. Then I tried connecting the pieces with ½-inch square steel tubing, but even though I buttressed the tubing and used right-angle brackets, it was still a shaky scope.

I might have made the Phase 2 style work, but I really didn't like the way the telescope looked. It looked like something I had thrown together quickly. It also required a 40-pound hunk of lead to balance right. And those long skinny struts rang like a tuning fork.

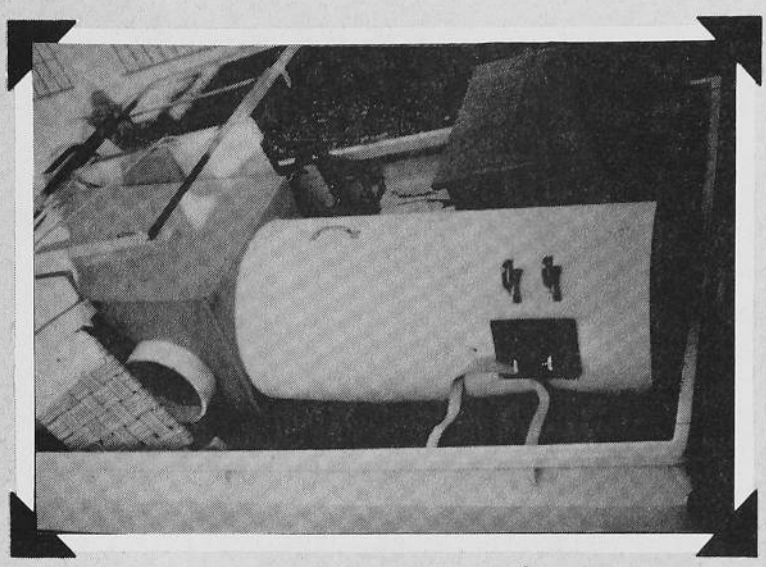
So I started the process all over again, designing an open tube set-up that would look good and perform well. I finally settled on building three boxes connected with shorter rods — Phase 3. This is the form the scope has today.

One problem I solved has to do with the mirror cell: in the conventional style, the tube can't be stood on end without setting the scope on the collimation bolts. Zap — time to recollimate. To alleviate this problem, I recessed the board that the mirror rests on into the mirror box.

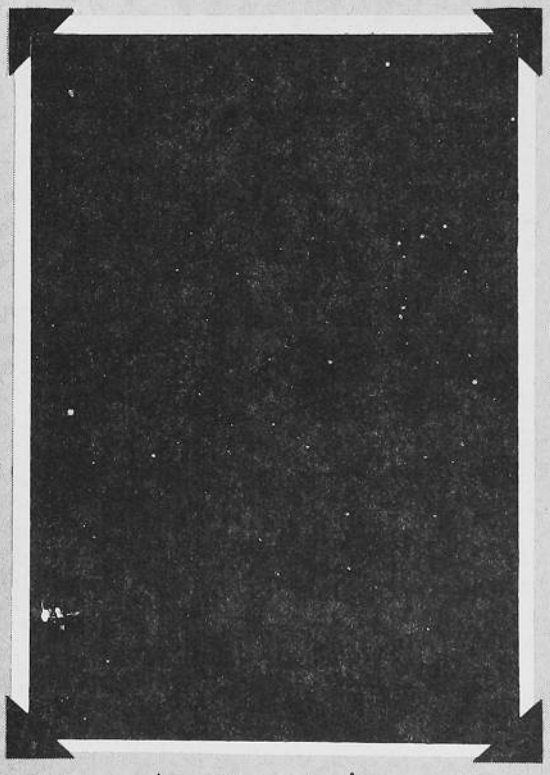
All three boxes are reinforced with right-angle brackets to maintain 90 degree angles. It's no good to fasten the boxes rigidly if they won't stay square themselves.

The connecting rods or struts require particular attention. With a trunnion box located in the middle of the tube assembly, the individual struts are shorter. I also made them out of ¾-inch square steel tubing for stiffness. The scope will be much easier to set up if the rods are interchangeable. When you drill the holes in the rods, use the first strut you drill as a template for the rest of the struts — drill through the holes in it to mark the position of the rest of the struts.

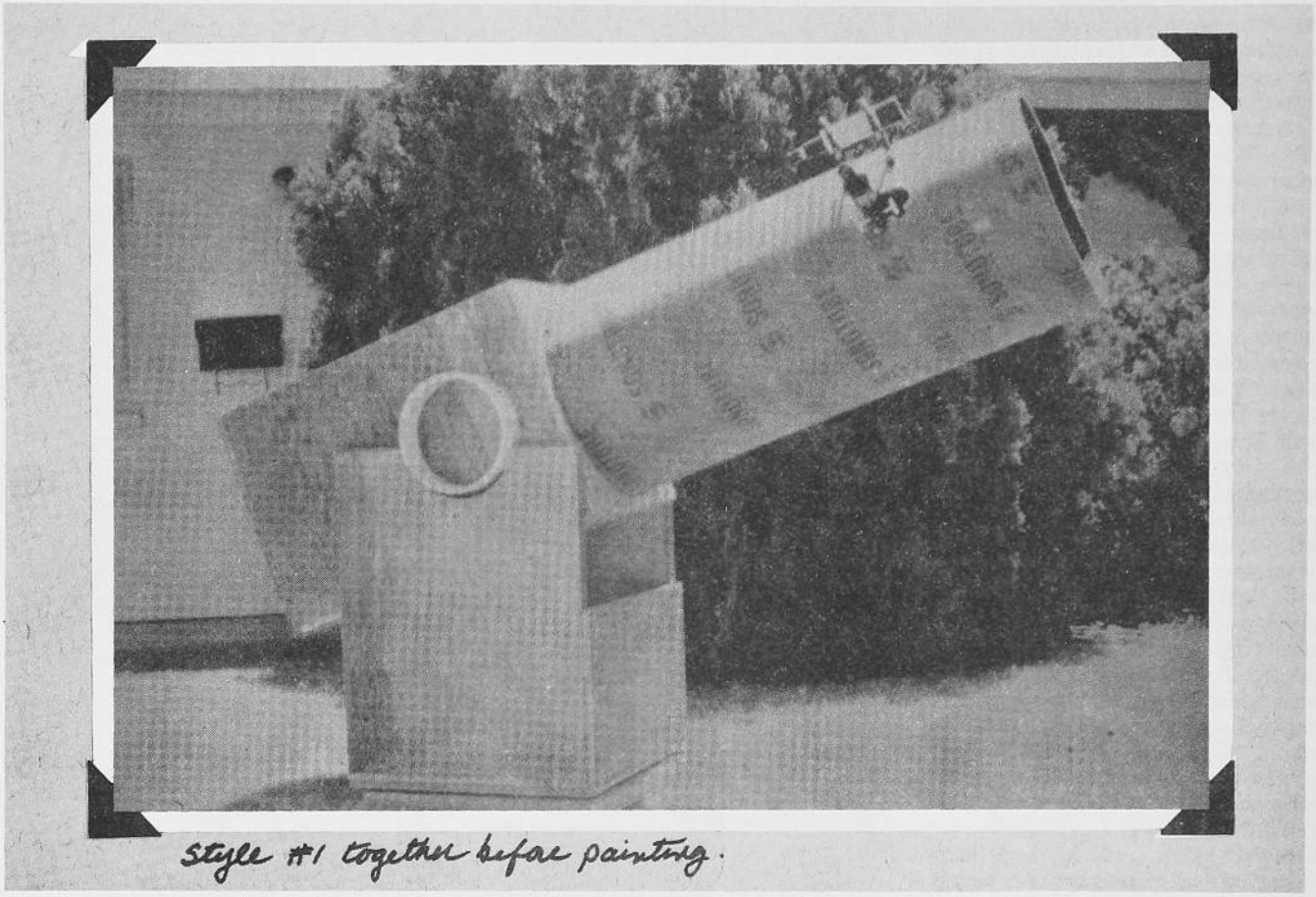
With these improvements, I can set up the telescope fairly easily in 30 minutes. A helper makes it much easier, and besides, I've gotten into the habit of having someone along to help. I hope the word doesn't get out that I can set up alone — my list of helpers might



A truck filled with telescope certainly discourages hitchhikers.



One minute of Orion and Sirius, then flash the scope.



Style #1 together before painting.

suddenly get short.

The present style has several other advantages. No longer must I handle the mirror every observing session. The mirror stays in the lower box during transport and comes out only for an occasional bath. The glass seems to cool much faster with the open tube assembly, and I have noticed that images are better right after twilight than they were with the Sonotube and box style. I believe that a well-designed scope assembled in this manner could be transported in a small station wagon or family sedan.

I think it is also important that the scope looks better in the Phase 3 mode than it did before. Let's be honest: we all want a scope that looks classy. At least I do.

Several people have asked me if the sky background is dark with an open tube assembly. Recently I set up next to another 17½-inch scope with a Sonotube tube, and the background didn't seem to be any better with the closed tube. My instincts tell me that a fairly deep box for both mirrors can provide plenty of baffling, though I haven't set out to verify it mathematically.

I hope to be a little more careful with Phase 4 (yes — another version of the chameleon telescope!) so the scope is a bit tighter. I've been using setting circles and an alt-azimuth conversion program on my TI-59. Although they consistently put an object in the finder field, it's chancier with the main scope. I don't plan to change the truss assembly, but I would like to do something with the too-big rocker box, either scale it down or make it knock apart for transport.

A transportable large aperture scope under clear Arizona skies is a dream come true. My scope has traveled to Riverside, and last year I took it to the Texas Star Party. (Yes, skies there are just as good as Arizona.) Viewing deep-sky objects in the 17½-inch makes all the time I've spend working on it seem even more worth it. I've identified globular clusters in the Andromeda Galaxy, seen the central stars of the Ring and Saturn Nebulae, and any of Messier's globulars is glorious with chains of stars and a blazing core.

Omega Centauri at the TSP has to be seen! I can see spiral structure in M-51, M-101 and M-74, just to name a few. And lots of observations made with this scope have appeared (or will appear) in *Deep Sky* under the "Arizona-Australia Connection" rubric.

If you've been thinking about building a larger instrument, then let me tell you it is worth it. I don't regret for a moment selling my "8" to finance the "17".

Let me leave you with two important tips about things I learned the hard way. Tip 1: Be careful with mirror clips. If you push the mirror against them too hard, you'll get fun-house star images. Tip 2: Take the time to collimate carefully. Short focus mirrors won't put up with much tilt before giving you fields full of comets. I use a Cheshire eyepiece during twilight for rough collimation, then fine tune when the first stars come out.

I have already mentioned several people who helped in making my dream a reality. I would also like to thank Earl Watts, a Riverside friend, for being patient with a ton of elementary questions, and Cliff Holmes for organizing Riverside so we have the chance to see each others' handiwork. Most of all, I want to thank Richard Berry for this magazine which gives every telescope-maker in the world a chance to exchange ideas — and that can only lead to more and better scopes for everyone.

Steve Coe
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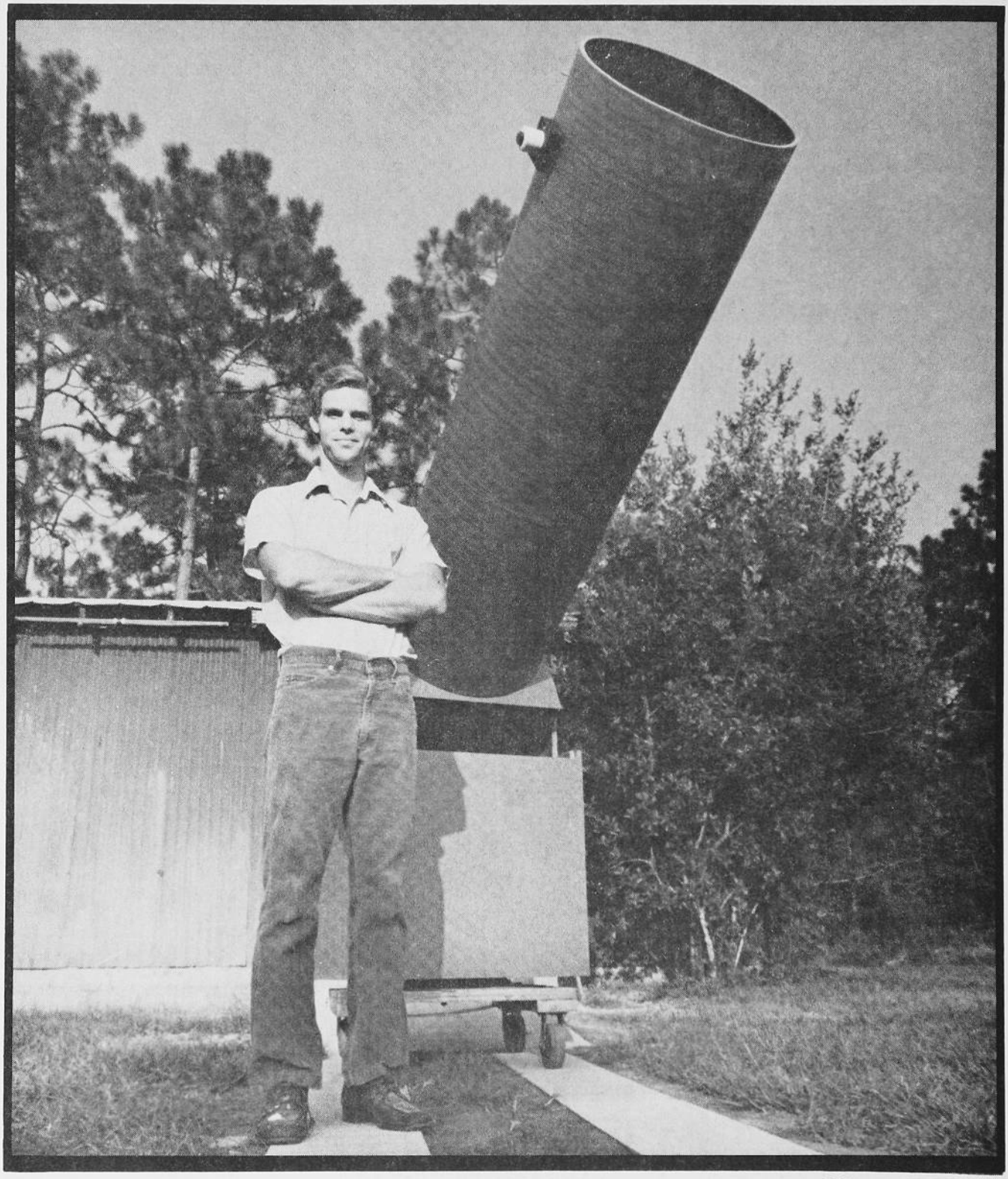
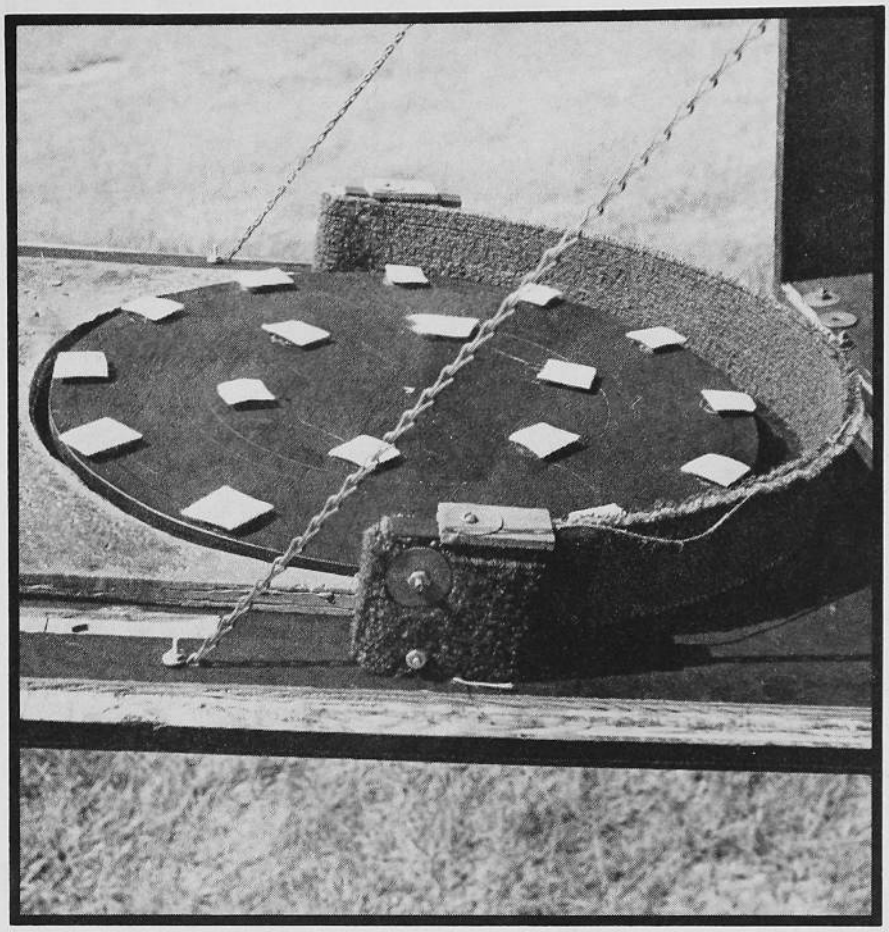
An Alabama Amateur's 20.5 Inch Telescope





Observing through my Dad's 6″ f/11 Springfield reflector kindled my interest in observing. While still in high school, I completed two telescopes from commercial 10″ and 14¼″ optics. Prior to starting the 20″, I had experimented with over a dozen mirrors and lenses ranging from 13″ refractors to 9″ reflectors made of ¼″ to ¾″ plate glass. One success was a 3″ solar telescope made from the glass found in a trash pile at a local glass shop.

The 20″ had the honor of being my first mirror shipped for aluminizing and is the first Pyrex disk I ever ground. From early trials I learned the techniques of mirrormaking with plate glass — and felt confident about pursuing the 20″. I studied Bob Kestner's articles over and over again prior to the arrival of the 1⅝″-thick fine-annealed disk from United Lens. I soon realized why Bob suggested starting a big, thin mirror career with a 16″.

Marshal Holman stands beside his completed 20.5″ telescope. Note that the focuser is a simple drawtube. The main tube of the 20.5″ reflector is 24″ diameter, and covered with Formica. The plywood rocker box is sheathed in tempered Masonite for a smooth finish. All photographs by Robert Bunge.

Grinding the Blank Round and Flat. Smoothing the 40-sided blank with a handheld grinding stone took 3½ hours on my grinding machine, but I expended another 31¼ hours with #40 aluminum oxide to grind the ⅛″ undulations from its surface. For this operation, I used a 40-pound weight on top of a 16½″ laminated plate glass-tiled grinding tool.

Grinding the Radius. The tool for grinding the radius was made of four pieces of ¼″ plate glass (that had been used in an old fish market) and a 7/16″ thick piece of glass table top. After gluing all these glass disks to make the 20½″ x 1½″ tool, I noticed that the tool was "pre-curved." Old table tops supported only around the circumference are often concave on top and convex on the bottom. Glue the glass with the convex side up.

Using full diameter strokes, it took me 23 hours of hand-grinding, with a 40-pound weight on top of the mirror, to reach the desired sagitta. When I finished roughing the curve, I wanted to set the mirror spherical, but it still had a gap at the edge even after 8¼ hours of ⅓-diameter strokes. The large grit size made it impossible to produce a true sphere.

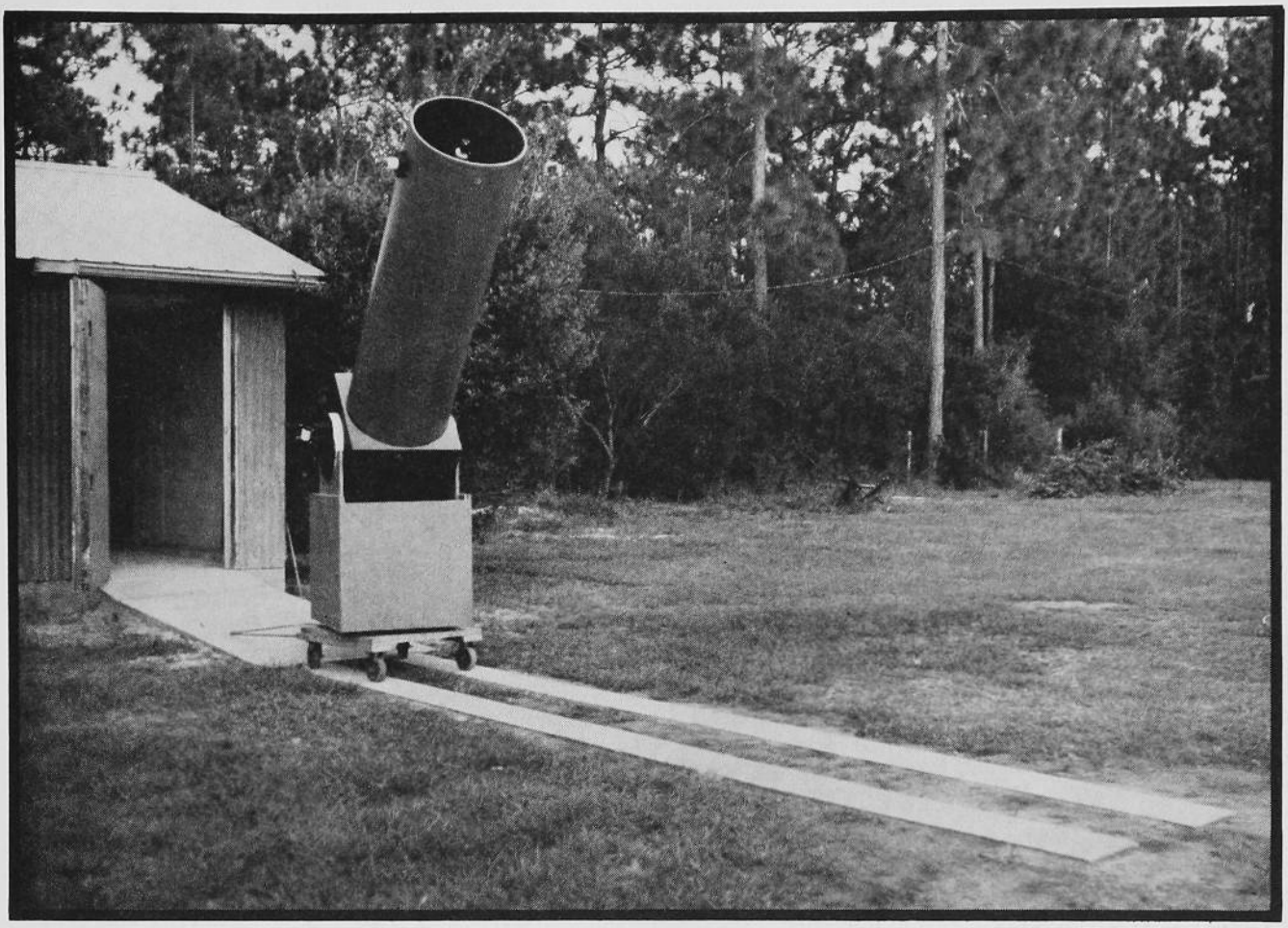
I molded a lead counterweight to fit around the mirror support system. Note the countersunk central bolt for locking the mirror support down against the collimating bolts.

Turning the "ears" over the primary to prevent its tipping forward. Unless the glass falls against them, the ears never touch the optical surface.

Fine Grinding. I used #120 aluminum oxide to smooth the very rough surface in 20 hours, then continued with 220, 320, 400, 600, and 5 micron until the mirror was fine-ground. On closer inspection, though, I discovered numerous pits over the whole surface, so I repeated the fine-grinding from #320. Before polishing began, I decided to regrind from #400 just to play it safe. These repeated sessions plus the methods described in Bob's articles paid off because all the test methods available to me showed no astigmatism. Although the finer abrasives were worked until the glass surfaces seemed to be touching, the mirror never seized.

Polishing. The 16½" tiled grinding tool became the base for the pitch lap for the 20½" mirror. After reading Bob's articles over several more times, efficient polishing began with 25 pounds placed on top of a plywood disk with three rubber pads at the lap's 70% zone. Using the thickest polishing slurry (as suggested by Mr. Kestner), I worked the lap until the slurry became thin and the friction between the mirror and pitch so great that my 8′ x 8′ polishing room began to smell like melting pitch. Because of the high friction, the lap was

Closing the tailgate for a night of observing. The factory-made saw-cut marks are just barely visible on the side of the thin mirror.



The telescope rolls easily along on concrete tracks so that one person can set up for observing. The handle (behind the rocker box) is removed during an observing session. The side bearing are made of three layers of ¾ plywood with a smooth plastic cover. The bottom bearing is 20″ in diameter.

held at about the 10 and 2 o'clock positions for the backward strokes and at 8 and 4 o'clock for the forward strokes. These strokes were velvety smooth and a very hard transition.

Polishing the 20.5″ didn't cause as many problems as other of my mirrors had. For getting an initial sphere, I used the Foucault and Ronchi tests indoors. The subdiameter tool was a new experience for me. The first error I made was using short strokes, which polished the center faster than the edges, so they really lagged behind. With a 6″ scalloped lap and very even tangential strokes, I was amazed at the results — as the edges gradually caught up with the center!

I then switched back to the 16″ lap, this time using too long a stroke and causing a broad turned edge. Shorter strokes corrected this some, but progress was extremely slow. To help it along, I worked the edge with a 4″ scalloped lap and then smoothed the whole surface with the 16″ lap again.

Disregarding the time spent with small figuring laps, the mirror was polished in just 13½ hours; if I had been thorough in my first attempt at fine-grinding, the total time would have been approximately 80 hours.

Figuring. I decide to test the paraboloid using stars, and, as you can guess, did things just like Bob Kestner suggests. The 16″ lap blended zones to produce a smooth surface, but with the 4″ and 6″ scalloped laps, I just worked until, with no more than four bands across the mirror, the bands appeared straight. Maybe Mr. Kestner shouldn't have mentioned the turned edge. Like he said, most amateur mirrors have them, and mine does, too. It goes unnoticed in normal observing. Using the Ronchi star test, the bands appear perfectly straight except at the extreme edge.

The views obtained with this thin mirror — a thickness that would have been scoffed at in the days of standard thickness blanks — exceed my expectations. Truly, my telescope is the fruit of Bob Kestner and Richard Berry's efforts to spread the art of telescope making, and the articles they have published in TELESCOPE MAKING magazine.

Marshal Holman
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■

Finishing Cardboard Telescope Tubes

Spiral wound cardboard has become very popular for telescope tubes. Although there are other sources, most of these tubes are forms for concrete columns. They are made of tightly wound cardboard and, in most cases, coated inside and out with wax. Marketed under trade names like Sonotube, they are available from suppliers of concrete construction forms.

I have worked almost exclusively with Sonotube, which is available in sizes from 6" to 42" inside diameter, in 2" steps. It is sold in 12-foot lengths. Larger hardware stores sometimes have 6-foot lengths of cardboard tube, but my experience has been that these are a thinner-walled variety. These should be adequate in some cases, especially for shorter focal ratios, if you install proper end rings. Some concrete form dealers also have such "economy" tubes.

The availability of these tubes is probably the main reason for their popularity. They can generally be purchased locally, avoiding the premium shipping usually accompanying the purchase of a telescope tube. They are easy to work with, and are much cheaper then fiberglass. Cardboard tubing has some other advantages. It has much better damping than fiberglass and is thermally more stable. The sizes available tend to force TMs to use a larger inside diameter than they would with fiberglass, which reduces the effects of air currents within the telescope. Of course, the larger diameter means that some commercial mirror cells and spiders must be modified to fit, and the tube will not fit in most commercial cradles.

Cardboard is heavier than fiberglass, but its main disadvantages are susceptibility to moisture and finishing difficulties. Since telescopes are used after dark, the necessity of having a finely-finished tube is debatable. Nonetheless, something must be done to protect the cardboard tube, especially the cut ends, from moisture. Since this requires some work, why not try to make a good-looking tube that you'll be proud of?

I use two methods to protect and finish cardboard telescope tubes. One involves covering the tube with cloth or other material — a method that produces a nice tube with a minimum of time and money. The second produces a tube that, though less resistant to dents and dings, rivals the best fiberglass in appearance, but requires building a special "tube lathe" and a good deal of work.

End Rings

With either method, I make a pair of end rings for the tube. The cut ends are very susceptible to moisture and easily damaged. The rings protect the ends, and greatly increase the tube's stiffness. Any Newtonian should have good end rings. It is unfortunate that those on many commercial instruments are obviously cosmetic, doing little to protect the tube and nothing to stiffen it.

I make end rings from plywood using a saber saw and a router. The saber saw is used for rough cutting and the router, mounted on a router table, finishes them to size. A carefully positioned pivot on the table permits smooth and accurate trimming of the rings.

My first "router table" was simply a plywood box rescued from an earlier project. The router was mounted under the box's top and a headless finishing nail driven into the top acted as a pivot. Both the outside and inside diameters of the rings are finished on the router table. The router, which is not shown in the accompanying diagrams, is mounted under the table. Only the router bit protrudes through the top, as seen in the photos. In the diagrams, the shaded portion is the piece being worked.

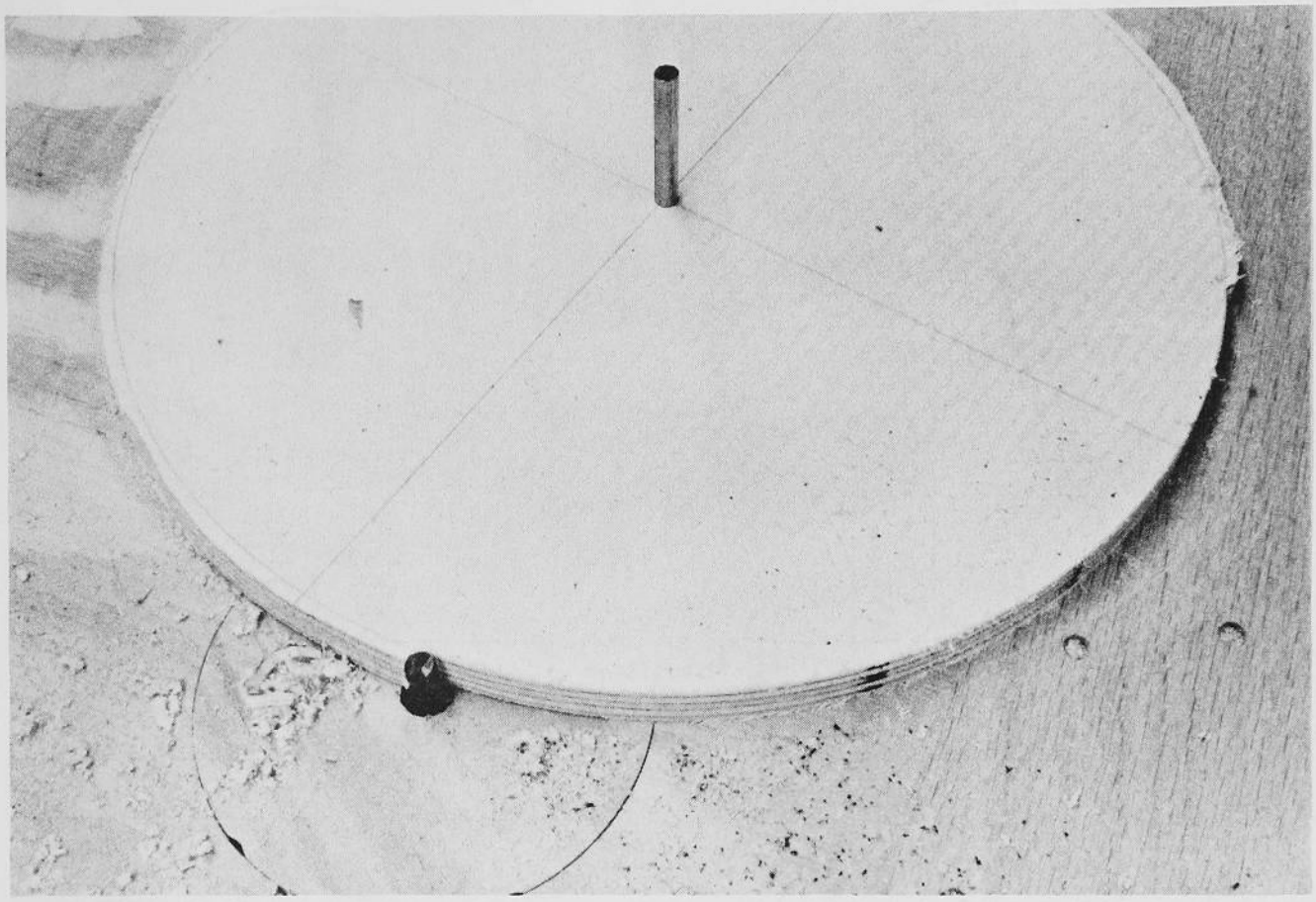
Finishing the outside of a ring. The safety disk is highly recommended, but was not used here so you could see the bit in the picture.

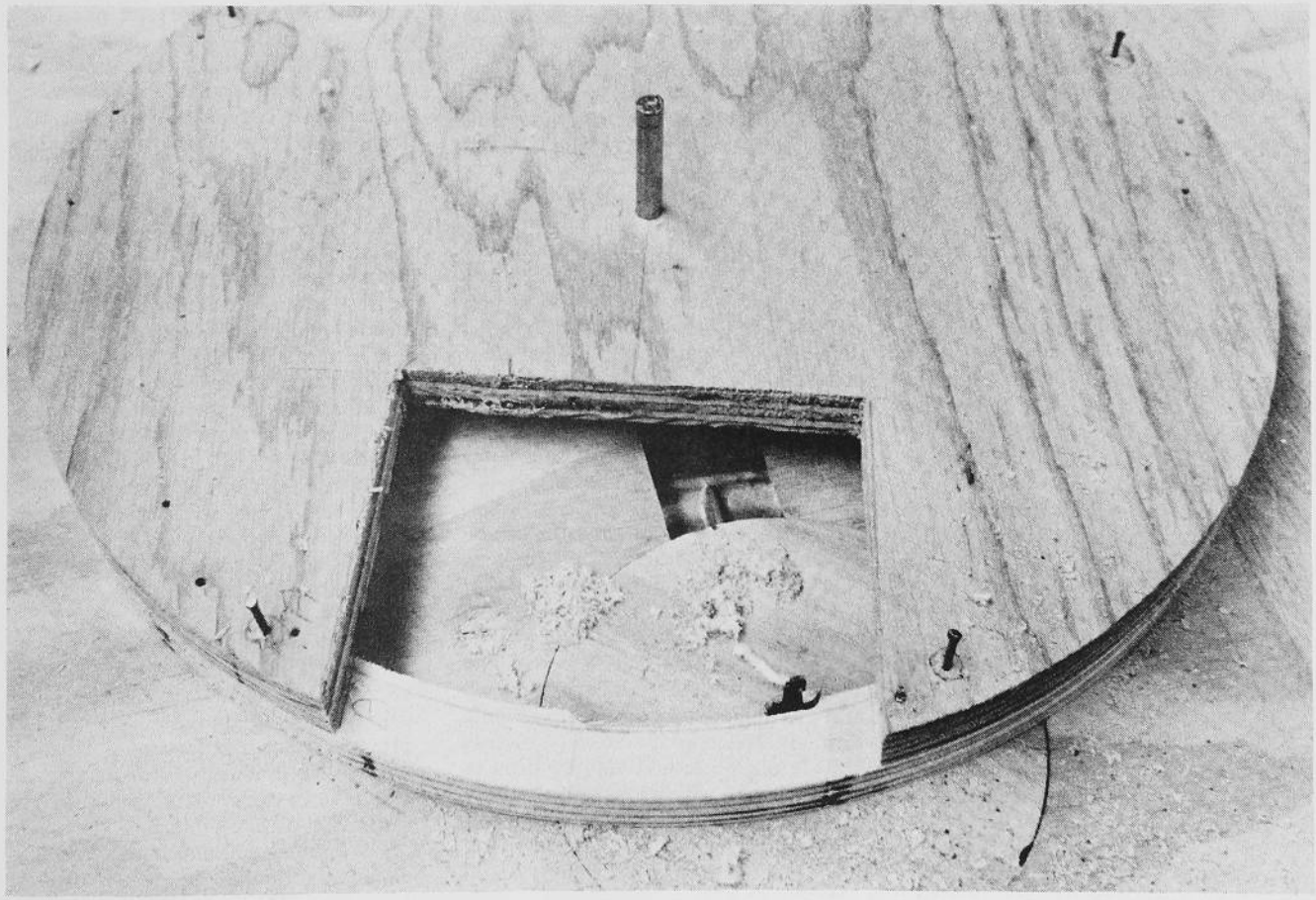
I usually build up each end ring from two rings of half-inch plywood. Both have the same outside diameter, but the inside diameters differ. One fits snugly around the tube, while the other has the same inner diameter as the tube. When they are glued together, the resulting end ring fits nicely over the tube end.

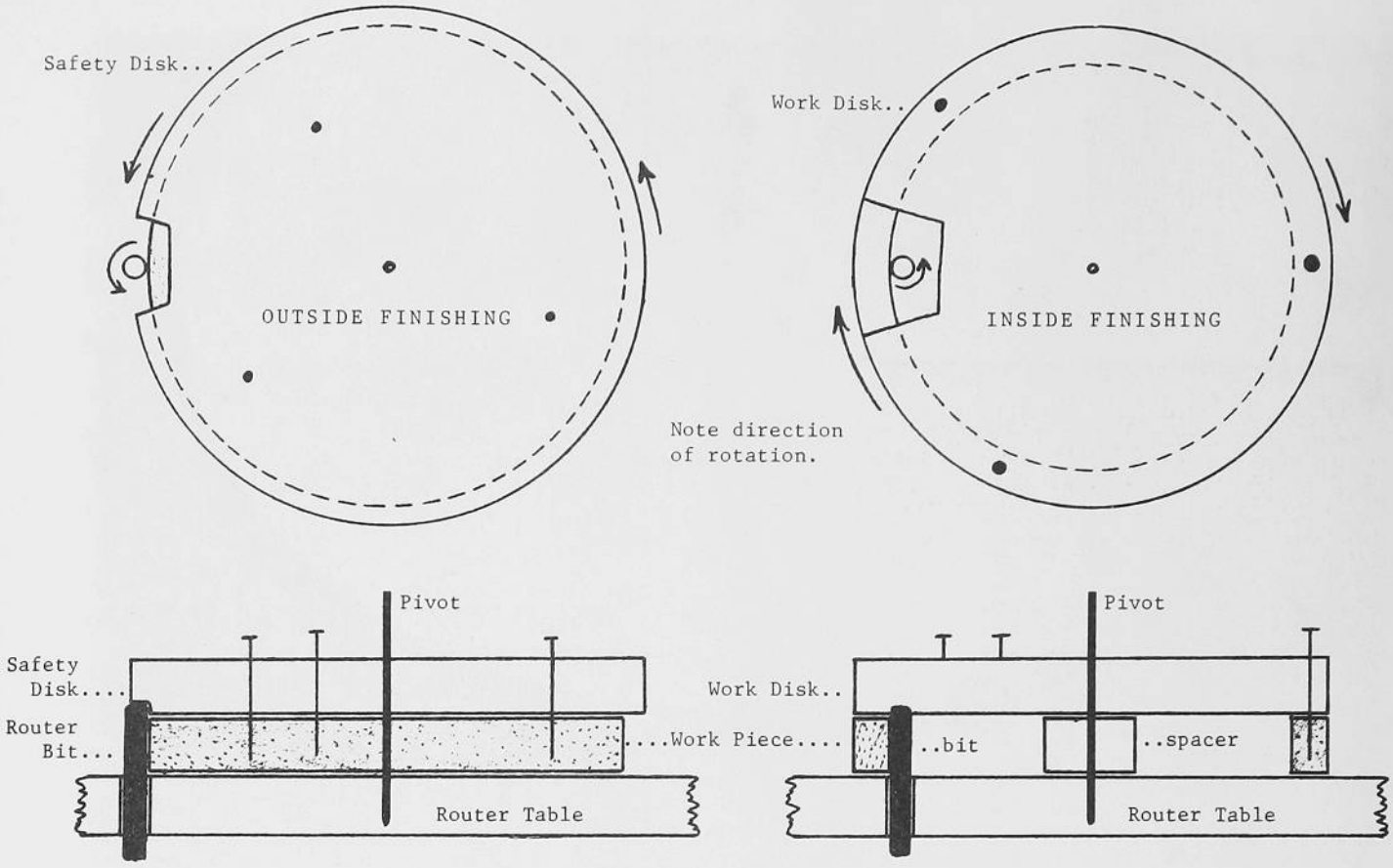
The rings are made by rough and finish cutting the outsides of all the disks, and then rough cutting and finishing the insides. Fill any voids revealed by rough cutting with wood filler before doing the finish cuts. For inside or outside finishing, the proper jig is assembled and the pivot is carefully placed at the proper distance from the router bit. Adjust the bit so it protrudes a little higher than the thickness of the work piece. Turn the router on and lower the jig down the pivot. Keep a firm grip on the jig as the router cuts through the piece. Once the work piece is flat against the table, begin turning it past the bit. Be sure to turn it into the cutting edge of the bit (counterclockwise for outside cuts, clockwise for inside). Keep a firm grip and maintain pressure against the table. When the entire piece has been trimmed, turn off the router while keeping a firm grip on the jig. Do not remove it until the router has stopped.

The glue used to laminate plywood is tough on bits. High speed steel does not hold up; carbide is worth the extra money. The bits wear fastest where they cut the glue layer, so you can

Finishing the inside of a ring. Be sure the pivot is at the rings' center when the work disk is attached.







extend their life by occasionally adjusting their height a little.

The upper disk shown in the diagrams is a "safety disk." It must be larger than the work piece so that it "hides" the bit from stray fingers. (Even so, exercise extreme caution when using this jig.) The upper disk is also needed to hold the partially finished ring when cutting inside diameters. For accurately concentric rings, it must be the same diameter as the rings being finished. The notches in the upper disks make the bit visible at the start and end of each cut.

The pivot should be long enough to go through the upper disk before the work piece encounters the bit. It should be fairly stiff, or the cuts will be out of round. The jigs are assembled with small nails. Make sure no nails go into the wood that will be removed by the router, and that none stick through the bottom of the jig.

Cloth Covering Tubes

The easiest way to finish Sonotube is to cover it with waterproof material or material that can be waterproofed. I always use cloth, and then spray it with fabric waterproofer. Large fabric outlets sometimes have astronomical patterns, and interesting patterns are available around Hallowe'en.

Cloth can be applied without removing the wax from the tube. This saves work and provides added protection from moisture. The seam from the overlap of the outer wax coated layer should be removed, otherwise you'll have a bump running barber pole style around the tube. The seam is easily removed using a sharp knife or single-edged razor blade.

Once this seam is removed you'll probably find a groove spiraling along the tube. Fill it with auto body filler and then sand flush. Don't miss any voids hidden under the ragged edges of the groove. The cloth (or other material) is then glued to the tube. I use white glue and allow a 2" to 3" overlap at the seam. Glue one edge of the cloth along the length of the tube. Then, gluing a few inches at a time, wrap the cloth around the tube. Glue the overlap down well. This process is easier if you have help.

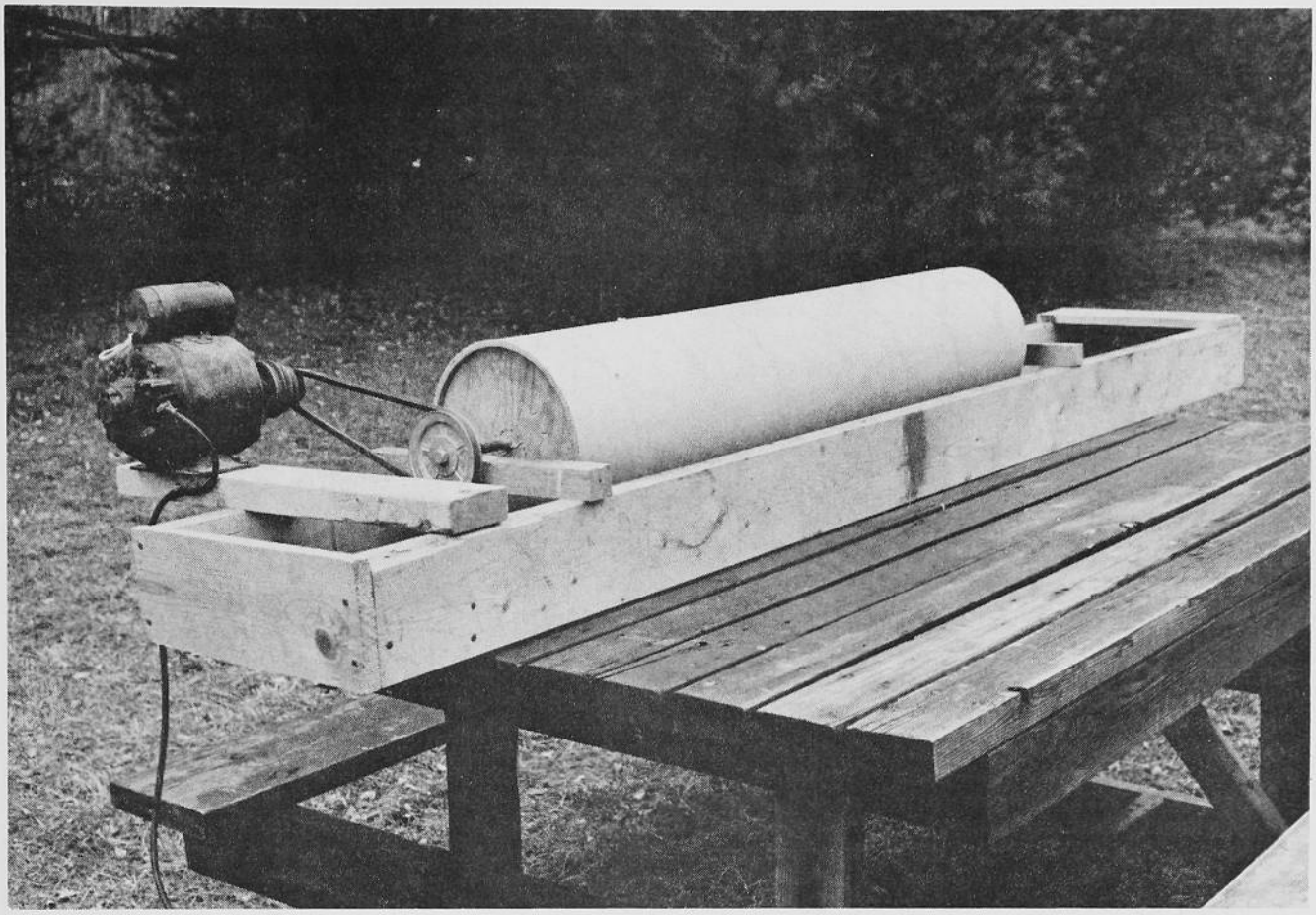
Glue seeping through the cloth can be a problem. Spread the glue as thinly as possible and avoid putting pressure on glued areas. You can support the tube between two chairs by running a board through it. Recently, I tried treating the cloth with waterproofer before gluing, and this helped keep glue from seeping through. Waterproof materials, such as vinyl or nylon, could also be used to cover tubes. I would like to hear about other materials and methods for covering tubes.

I was concerned that the cloth would come up along the seam or would not hold well enough to the wax, but a 12" tube that Susan Smith covered five years ago is still fine after a great deal of use. End rings protect the vulnerable ends of the covering. Allow for the thickness of the covering when making the rings.

Blackening the Inside

The wax must be removed from the inside of the tube so it can be finished flat black. Fortunately, this is quite easy to do — simply locate a corner of the inside spiral cardboard winding at one end of the tube and gently peel back a thin layer of cardboard with the wax on it. Grasp the freed corner and pull to peel this layer from the inside of the entire tube. It will usually come out easily. It if tears, simply restart it, either at the same place or at the other end. I have never had trouble doing this with Sonotube, but I recently had a terrible time with a thinner-walled economy tube.

Cut or sand out any loose bits of cardboard. I then coat the inside with two generous coats of auto body filler-primer. It protects the cardboard and provides a nice base for a good flat black paint. Auto body filler-primer is available in spray cans, but they are somewhat difficult to use on the inside of the tube — and any kind of paint is expensive bought in spray cans. I



The tube lathe shown as I use it, atop a sturdy picnic table. The tube shown here has no end rings, but is desirable to finish the tube with the end rings attached.

bought the primer filler (or primer surfacer) in cans from an auto body paint store. The canned formulation is thinner; it's supposed to be applied with a paint sprayer, but I had no problems brushing it on.

Building a Tube Lathe

The tube lathe is a simple machine designed to turn Sonotube at about 100 r.p.m. for the finishing method described below. The lathe bed is a frame of 2x6s, and must be wide enough to accommodate the largest diameter of tube to be worked, and long enough for the longest. Some means of supporting the frame at a comfortable working height must be provided. I place my lathe on a heavy picnic table, but properly braced legs could be added easily. Although the lathe was primarily for turning tubes at high speed, it is also handy for holding tubes while working by hand.

The lathe bearings are long half-inch bolts running in bushings. The bushings are supported by 2x2s across the frame and are held to the crosspieces by U bolts. The crosspiece near the motor mount is fixed, but the other one can be moved to accommodate different tube lengths. Special jigs that fit inside the tube hold the ½"-bolt axles. The key to smooth operation is properly centered axles running precisely along the tube's axis.

To ensure proper axle centering, I make disks of ½" plywood that fit snugly inside the tube. Half-inch holes drilled precisely in their center accommodate the axles. To keep the axles from being skewed, each axle runs through a pair of disks firmly attached to 2"-thick spacers. The jigs are the only really critical lathe part, so I will describe how I make them accurately. Other methods of holding the tube in the lathe will probably occur to more experienced wood workers.

The disks can be made accurately round the same way the outsides of the rings were. Cut the disks slightly oversize and then finish them using the router table. To ensure that the ½" holes are accurately centered, drill them before finishing the disks. Replace the normal router table pivot with a ½" bolt. All holes must be straight, so use a drill press or drill aligning jig. Forstner or brad-point wood drills produce rounder and better-fitting holes than common wood bits.

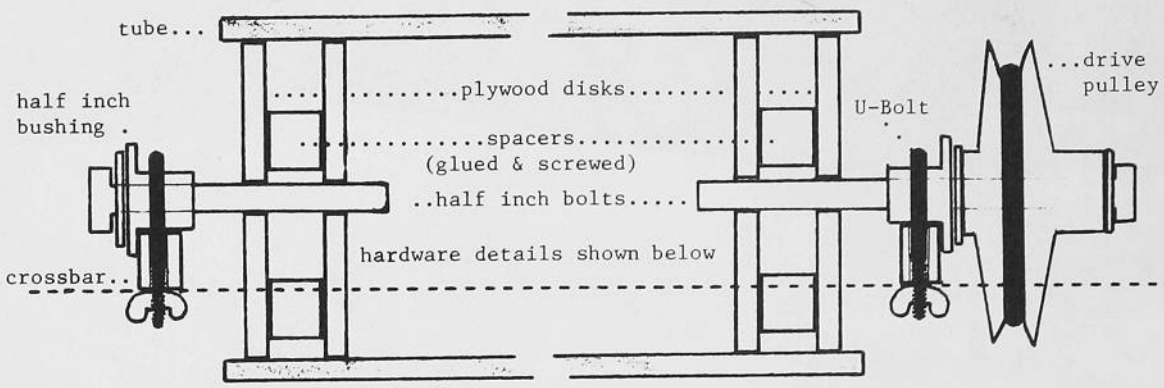
The disks must fit snugly inside the tube. To simplify sizing the disks, I modified my router table so the ½" pivot hole was in a separate piece of wood that could be moved fractionally toward the router bit to sneak up on the correct size. If I overdo the final cut and the disks turn out slightly smaller than desired, I wrap two layers of of masking tape around each disk for a snug fit.

The disks must be accurately aligned when glued to the three spacers. To ensure this, place a ½" bolt through one disk and bolt it to the second using nuts and washers on each side. Now screw and glue each disk to the spacers. Drill several 1" holes through both disks in one jig. If you have trouble removing the jigs when the tube is done, run a long dowel or broom handle through these holes and knock out the jig at the other end.

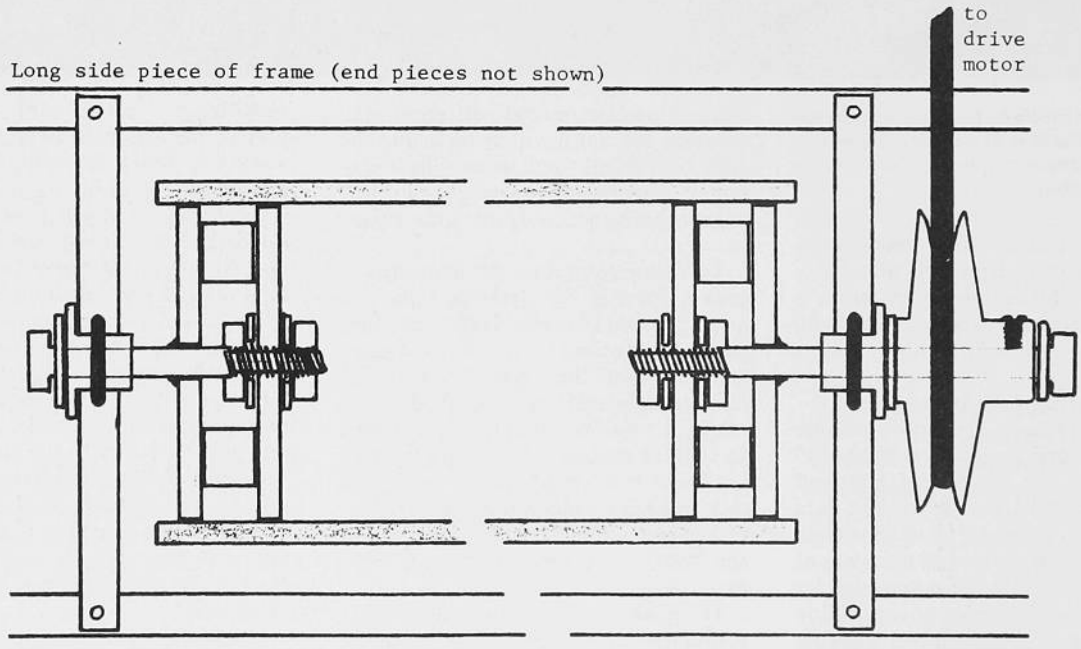
Install the ½" bolts in the jigs. When the jigs' outer disks are about ½" inside the tube, one bolt must be long enough to span the crosspiece, and the other must be long enough to span the crosspiece and hold the drive pulley. If you are finishing the tube with the end rings installed, extra clearance will be needed between the tube ends and the crosspieces. (Be sure your end rings allow the jigs to pass through them!)

The axles must be securely bolted to the disks. I tighten the inside nut against the bolt's shoulder and use fender

THE TUBE LATHE



SIDE VIEW

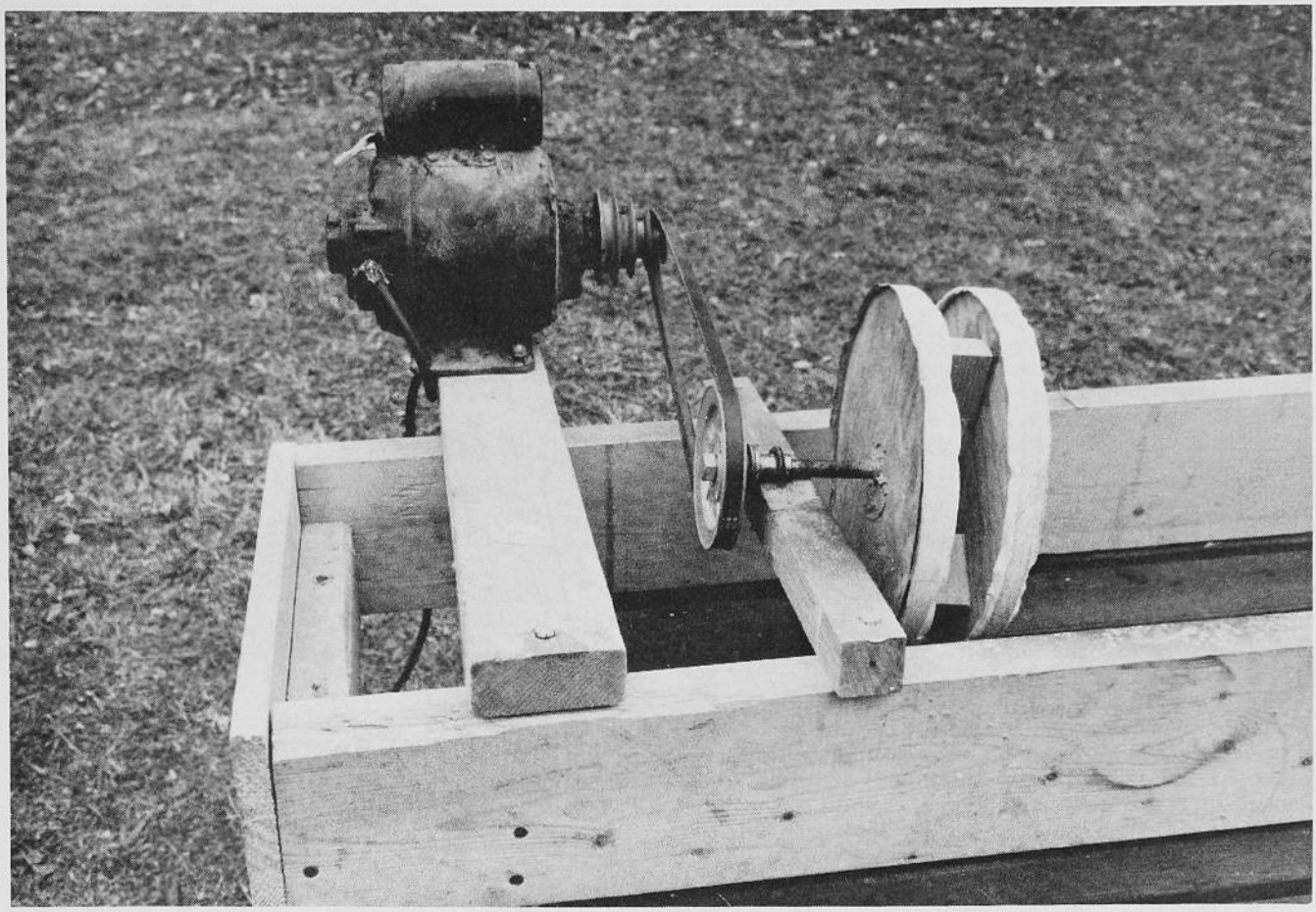


TOP VIEW

Not to Scale
(or even close)

washers on both sides of the disk. If there is enough thread on the bolt, secure the outside nut by tightening another nut against it. You can also epoxy everything when done, including where the axle passes through the outside disk. Be sure to place the bushings and other hardware on the axles before bolting them to the jigs.

Slide the completed jigs into the tube. The outside disks of the jigs should be about ½″ inside the tube. If the jigs are not tight, wrap tape around them until they fit snugly. If you are finishing the tube with the end rings on, slide them



The tube lathe, showing the details of the motor mount and the driven jig.

onto the tube. Do not glue them on until the lathe is assembled. Turning the lathe by hand provides an accurate way to adjust and square the end rings when they are glued.

Place the drive end of the tube on the frame's fixed crosspiece. Place a U bolt over the bushing and tighten it down. The other crosspiece goes under the remaining bushing where it will allow no longitudinal play in the bearings. Nail down this crosspiece and clamp the bushing with a U bolt.

Check the alignment of the axles by rotating the tube by hand. It will probably be a little wobbly. You can change the alignment by lightly hitting the outer edges of the jigs with a mallet. Once the rotation is fairly smooth make sure there is still no longitudinal play in the bearings. Adjust the crosspiece if there is. Run the lathe briefly to see if the tube turns smoothly. It it does, run beads of silicon adhesive between the outer disks and the tube's inner wall. This will help ensure that things stay aligned.

Finishing the Outside

A superior tube can be made by removing the wax from the tube and then building up a smooth surface using auto body filler and sandable primer. It would be possible to do this entirely by hand, but I wouldn't want to try it. The "tube lathe" speeds up the process.

I have heard horror stories about removing the wax from the outside of Sonotube, stories involving gallons of solvent and lots of heating and scraping. A local amateur, Susan Smith, discovered it is easy to peel off the wax with a thin layer of cardboard. The secret, with Sonotube anyway, is to start at the wrong end of the tube, that is, to start peeling at the end that was wrapped first when the tube was made. This means peeling off the overlap first, and then the main wrap of cardboard. The resulting surface is a little rough for painting, but it is ready for filling and smoothing on the tube lathe.

I use auto body filler and primer filler (primer surfacer) to get a smooth surface on the tube. A fiberglass resin could also be used, and there are probably some other possibilities. As with the inside, I mixed primer surfacer since it's thinner and brushed it on. Remove any rough patches from the cardboard with coarse sandpaper. Fill the spiral groove running around the tube and any dings and dents with auto body filler. Beware of voids lurking under incompleted exposed portions of the groove. Sand the filled areas even with the rest of the tube then apply several coats of filler primer and sand. Continue painting and sanding, changing to finer sandpaper as appropriate, until the tube is nice and smooth. Strong oblique lighting from one end of the tube will reveal uneven areas. Smoothing may go slowly at first, but your technique will improve with experience.

You can sand the end rings while the tube is in the lathe. Fillets of body filler between the inner edges of the end rings and the outside of the tube are a good idea. Once the tube and end rings are quite smooth, fill and sand by hand for a final smoother finish. Paint the tube with automotive spray paint. The paint will go further if you turn the tube slowly by hand instead of using the motor. I commissioned an artist friend, Jane Morgan, to paint deep sky objects on my tube, and it looks very nice.

My thanks to Susan Smith for help both with finishing tubes and with this article, and to Bob Mulford for help with the prints used here.

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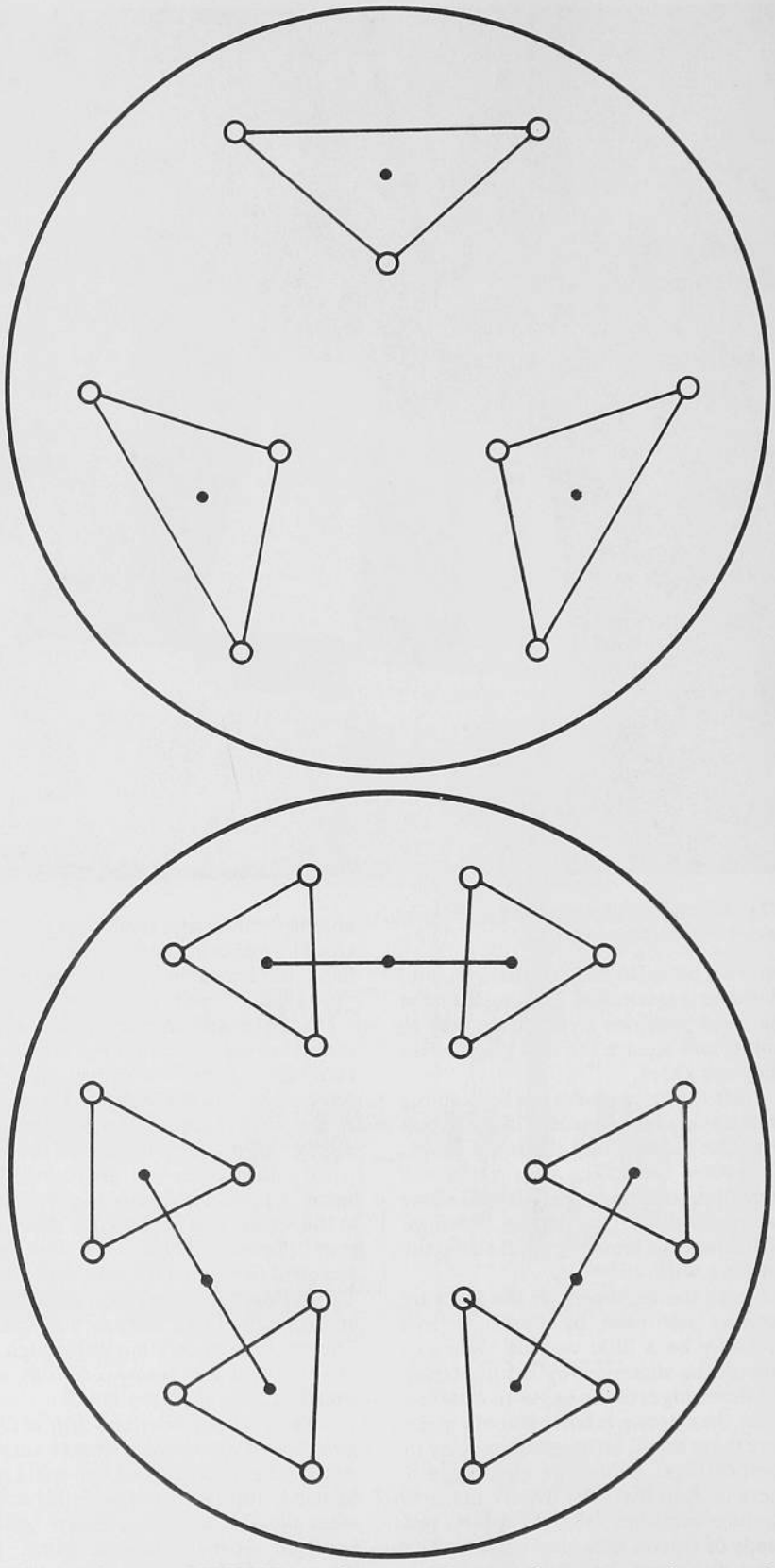
Flotation Cell Design



Mirror cell design is an important consideration in home-built telescopes, especially in Dobsonians with large, thin mirrors. For small mirrors, a three-point support is all that is needed. (Some people take the word "point" too literally. The support points should be small pads of felt, cork, Teflon, or other materials.) For larger mirrors, more points are needed to share the weight. The trick is to locate the points so they share the load equally, and to ensure that they all remain in contact with the mirror. The solution is something called a flotation cell. A nine-point flotation cell has three triangles supported at their centroids. The triangles should be free to wobble on their supports so they maintain equal contact with the mirror, but they must be constrained so they do not rotate out of position. An 18-point flotation cell is built on the same principle except it has six triangles, supported in pairs by three crossbars, supported in turn at their centers.

The problem is how to locate the support points so they will share the load evenly. There are different ways to approach the problem, but the simplest way is to divide the mirror into segments of equal weight, then place the support points at the center of mass of each segment. For the nine-point flotation cell, the mirror is divided into an inner and outer zone. The outer zone is divided into six segments and the inner zone is divided into three segments. Each of three triangles supports two outer segments and one inner segment. For an eighteen-point flotation cell, the mirror is divided into an inner and outer zone, but the outer zone is divided into 12 segments and the inner zone is divided into 6 segments.

Deriving the formulas for dividing the segments into equal weights and locating their centers of mass is a good calculus review problem. I took into account the varying thickness of the glass determined by the f/ratio, and the possibility of a central hole. (These considerations are negligible in most cases, but what the heck!) The BASIC program included here uses the resulting equations to calculate the location of the support points and the dimensions of the triangles and cross bars for 9 and 18 point flotation cells. It is written for a TRS-80, but users of other computers should find it understandable. (LPRINT is the TRS-80's way of printing the result on a lineprinter. These can be replaced by ordinary PRINT statements for screen display.) The inputs can be in any units (inches, cm, etc.) and the outputs will be in the same units.

The sample runs are for a typical setup — a 17″ f/4 mirror 1.5″ thick (after grinding), with no central hole.

Dave Chandler
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La Verne, CA 91750

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10 CLS
20 PRINT"NINE AND EIGHTEEN POINT FLOATATION CELL COMPUTATIONS"
30 PI=3.14159
40 PRINT:INPUT"9 OR 18 POINTS";P
50 IF P=9 THEN C7=1.5 :C8=1.0472 :C9=.5236 :GOTO 70
60 C7=3 :C8=.5236 :C9=.2618
70 INPUT"DIAMETER OF MIRROR";R3
80 INPUT"DIAMETER OF CENTRAL HOLE (0 IF NONE)";R1
90 INPUT"THICKNESS OF MIRROR AT EDGE";H
100 INPUT"FOCAL RATIO";FR
110 F=FR*R3
120 LPRINT"-----------------------------------------------------------------"
130 LPRINT P;"POINT FLOATATION CELL COMPUTATIONS FOR A MIRROR WITH"
140 LPRINT"DIAMETER =";R3;"/ CENTRAL HOLE =";R1
150 LPRINT"EDGE THICKNESS =";H;"/ FOCAL LENGTH =";F;"/ FOCAL RATIO =";FR
160 LPRINT"-----------------------------------------------------------------"
170 LPRINT
180 R3=R3/2
190 R1=R1/2
200 H=H-R3*R3/4/F
210 C=-2*R1^4-R3^4-16*F*H*R1*R1-8*F*H*R3*R3
220 B=24*F*H
230 R2=SQR((-B+SQR(B*B-12*C))/6)
240 V=((R2^4-R1^4)/16/F-H*(R1+R2)*(R1-R2)/2)*PI/C7
250 C1=((R2^5-R1^5)/20/F+H/3*(R2^3-R1^3))/V*2*SIN(C8)
260 LPRINT"RADIUS OF INNER SUPPORT POINTS =";C1
270 C2=((R3^5-R2^5)/20/F+H/3*(R3^3-R2^3))/V*2*SIN(C9)
280 LPRINT"RADIUS OF OUTER SUPPORT POINTS =";C2
290 LPRINT:LPRINT"TRIANGLES ARE ISOSCELES WITH:"
300 LPRINT"BASE =";C2*2*SIN(C9)
310 A=C2*COS(C9)-C1
320 LPRINT"ALTITUDE =";A
330 LPRINT"BALANCE POINT =";A*2/3;"FROM THE VERTEX"
340 IF P=9 THEN 380
350 LPRINT
360 LPRINT"LENGTH OF BAR CONNECTING TRIANGLES =";C1+A*2/3
370 LPRINT"RADIUS OF CENTER POINT OF BAR =";(C1+A*2/3)*COS(C8)
380 LPRINT:LPRINT:END
```

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-----------------------------------------------------------
 9 POINT FLOATATION CELL COMPUTATIONS FOR A MIRROR WITH
DIAMETER = 17 / CENTRAL HOLE = 0
EDGE THICKNESS = 1.5 / FOCAL LENGTH = 68 / FOCAL RATIO = 4
-----------------------------------------------------------

RADIUS OF INNER SUPPORT POINTS = 2.81512
RADIUS OF OUTER SUPPORT POINTS = 6.64932

TRIANGLES ARE ISOSCELES WITH:
BASE = 6.64933
ALTITUDE = 2.94336
BALANCE POINT = 1.96224 FROM THE VERTEX


-----------------------------------------------------------
 18 POINT FLOATATION CELL COMPUTATIONS FOR A MIRROR WITH
DIAMETER = 17 / CENTRAL HOLE = 0
EDGE THICKNESS = 1.5 / FOCAL LENGTH = 68 / FOCAL RATIO = 4
-----------------------------------------------------------

RADIUS OF INNER SUPPORT POINTS = 3.25062
RADIUS OF OUTER SUPPORT POINTS = 6.88388

TRIANGLES ARE ISOSCELES WITH:
BASE = 3.56337
ALTITUDE = 3.3987
BALANCE POINT = 2.2658 FROM THE VERTEX

LENGTH OF BAR CONNECTING TRIANGLES = 5.51642
RADIUS OF CENTER POINT OF BAR = 4.77736
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An Alt-azimuth Mounting with Equatorial Drive

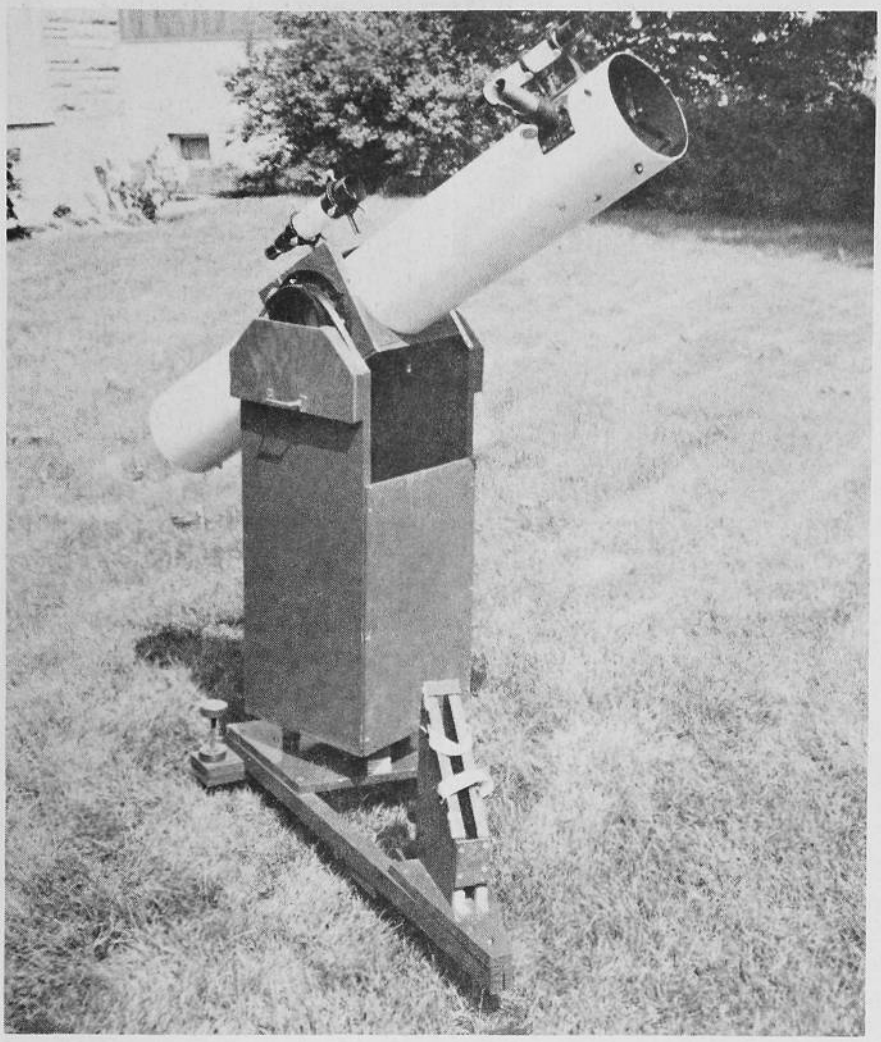
Some years ago, amateur telescope makers almost always selected an equatorial mount for their telescopes. This mount allowed one to easily locate stars and celestial objects using setting circles, and, in addition, to follow their movement in order to photograph them.

Recently, however, many amateurs have constructed alt-azimuth instruments known as Dobson telescopes — named after John Dobson, an amateur astronomer and astronomy popularizer in San Francisco. This type of mount became very popular because of its portability and simplicity. The axes of the Dobsonian mount slide on pieces of slippery Teflon plastic which produces a smooth and uniform motion. Its design and form virtually insure that the mounting is very stable.

Some Dobsonian owners convinced me to make a Dobsonian mounting, and I put away my old equatorial mount. However, this mount has one major inconvenience: it cannot easily follow the stars as they move across the sky, making it seem impossible to photograph the sky using a Dobsonian.

Until recently, I only knew two ways to track stars with this kind of mount. The first consists of placing the Dobsonian mount on a Poncet table. The Poncet is an equatorial mount with a limited ability to move in right ascension. The second way is to drive the axes of the alt-azimuth Dobsonian with two motors while rotating the tube about its axis. One must then program a computer to drive the motors adequately in order to reproduce an equatorial movement — difficult for an ordinary guy like me. The complexity of such a system makes an equatorial more cost effective.

However, in the last few months I



have worked out a third method of adding a tracking mechanism to the Dobsonian mount which insures good tracking and guiding on the stars. The mechanism replaces a motor on altitude axis and eliminates the need for computer control by means of a simple mechanical driving system. Furthermore, I eliminated the need for a motor to rotate the tube along the optical axis by piggybacking my camera on the driving system rather than the telescope.

I am really satisfied with my modified Dobsonian mount. This one won me the First Originality Award at Stellafane in Springfield, and Most Innovative Component at the annual meeting of Amateur Astronomers Association at Montreal and annual meeting of telescope makers organized by the Astronomical Society of Montreal. I am very glad to have contributed to the advancement of amateur astronomy and telescope making.

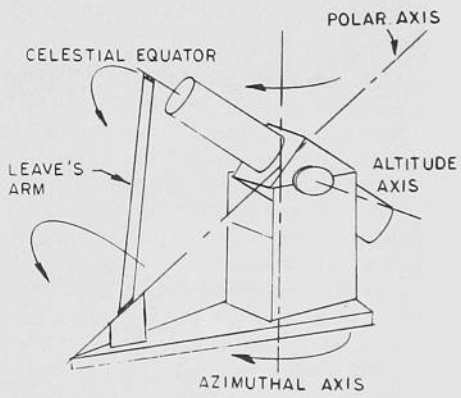
I am providing complete drawings in the hope that once others have tried my idea, they will be able to go further with it than I have. I would be happy to see ATMs continue to develop such mounts because, of course, there is always room for improvement.

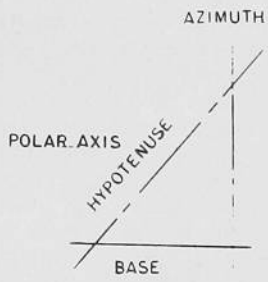
The Theory of the Mount

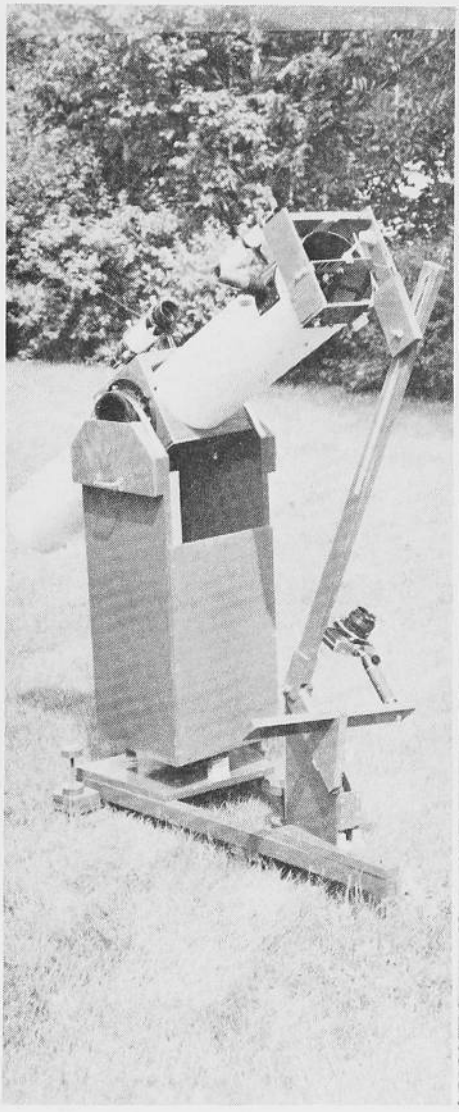
The principle by which a Dobsonian alt-azimuth mount can track the sky dates back quite a while. The only example I've ever heard of is the "Earl of Crawford equatorial mount," which seems unused until today. The references specified that this method could be applied to track the stars in the southern celestial hemisphere only.

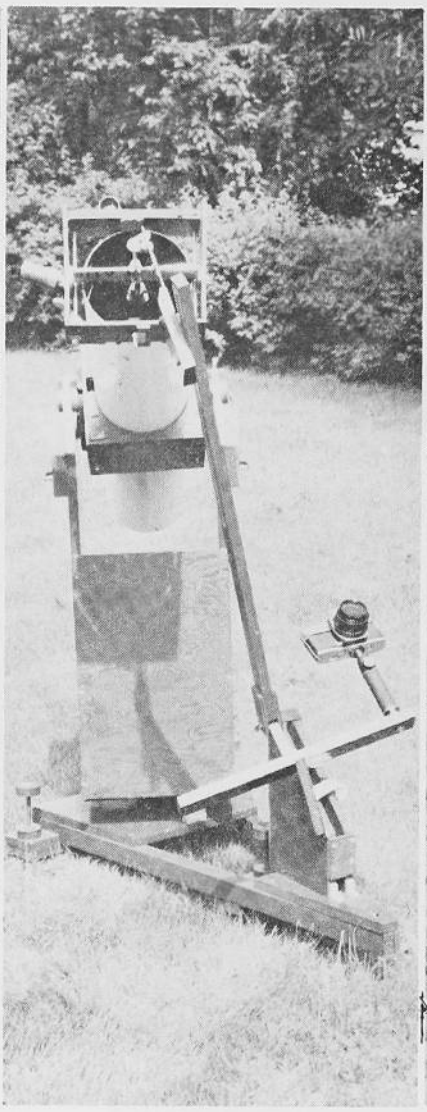
As you can see from the drawings, on my mount, the vertical axis is azimuth and the horizontal one is altitude. However, I added a third axis to the system: a polar axis. I put it in such a way that the three axes intersect at a common point.

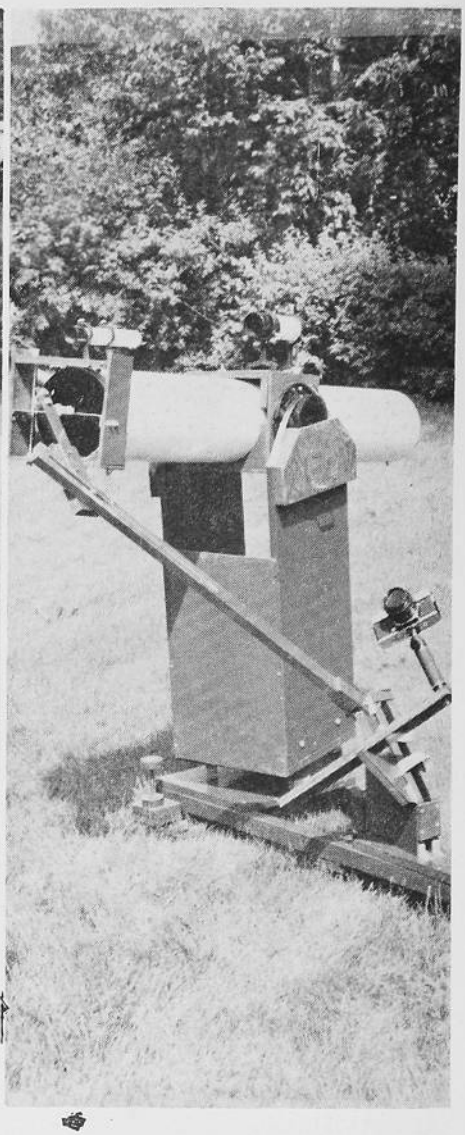
Now suppose you add an arm extending from the polar axis to the end of the tube. When you rotate the mount around its azimuthal axis, the telescope will automatically follow an equatorial path. In addition (as we shall see later), the telescope can be driven by a motor on the azimuthal axis and the arm will serve as a guide for the telescope.





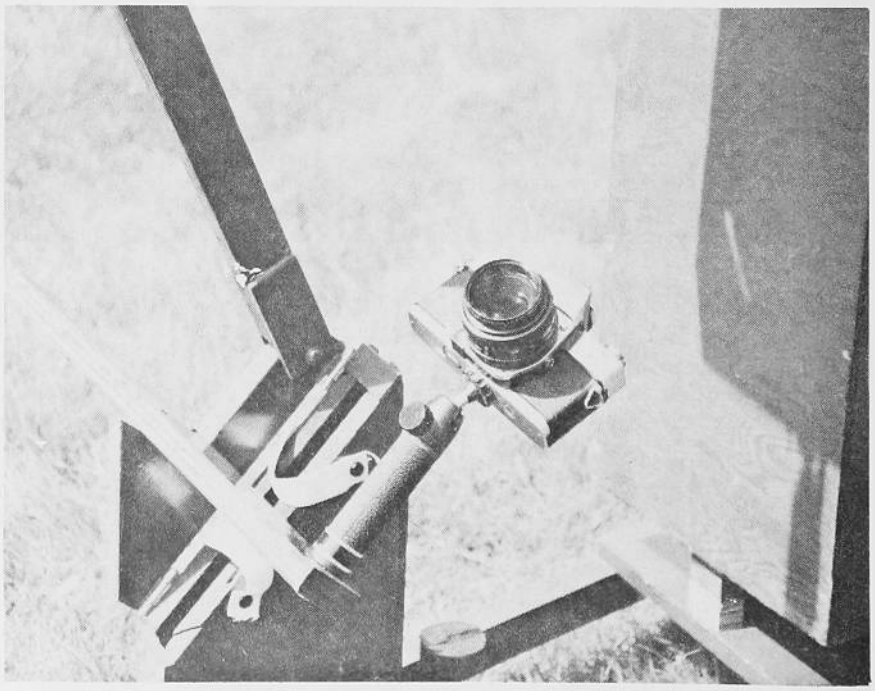


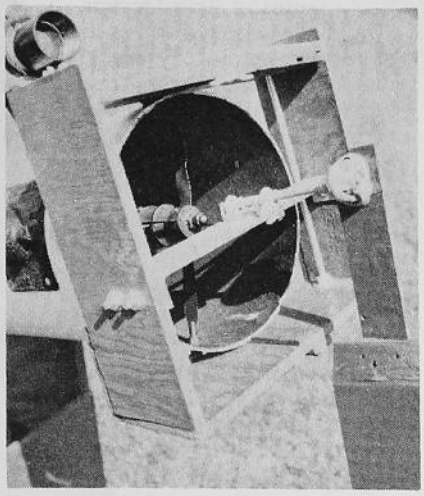


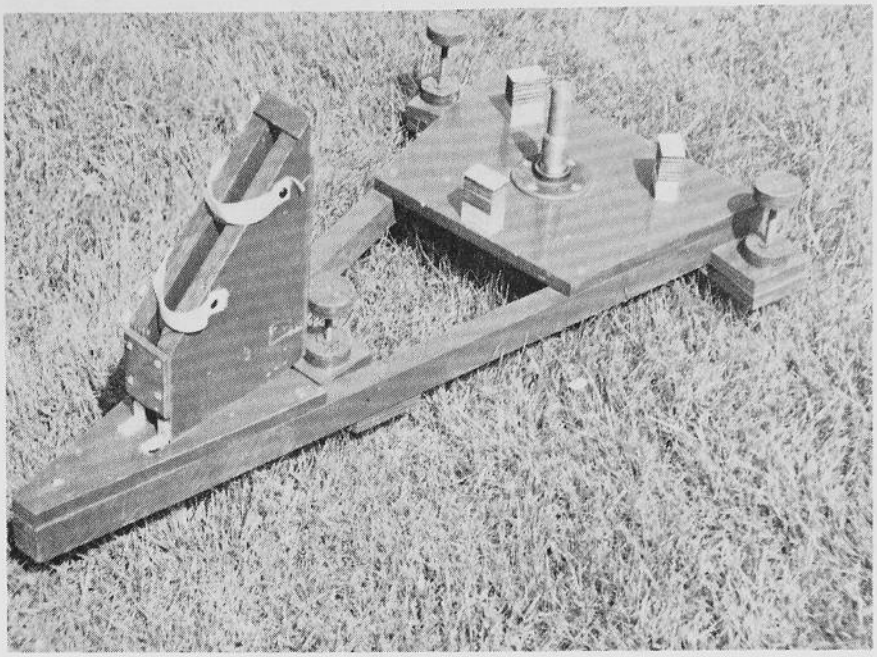


The sequence of photos illustrates the behavior of the arm-guiding system. Note that the camera should be attached to the guiding arm and not to the tube of the telescope because although the tube will point correctly, it does not rotate about its own axis so instead the field will rotate.

In my preliminary design, the arm followed the tube with a strap hinge attached just below the tube. (The hinge is still present in many of the pictures.) However, I soon saw that this system did not work properly because the attachment was not in the rotational axis of the tube. The effect was to advance the guiding arm with respect to the tube's axis after a few minutes of guiding. I calculated that a 5° error arises during 6 hours of tracking — enough to produce a significant error after just a few minutes. Therefore I modified the attachment of the arm to the tube. The arm now attaches behind the spider and is aligned with the optical axis. A nut on the bolt rotates around







the tube's axis while the tube rotates around the azimuth axis. I use the telescope as a guide to follow a particular star situated as close as possible to the celestial equator.

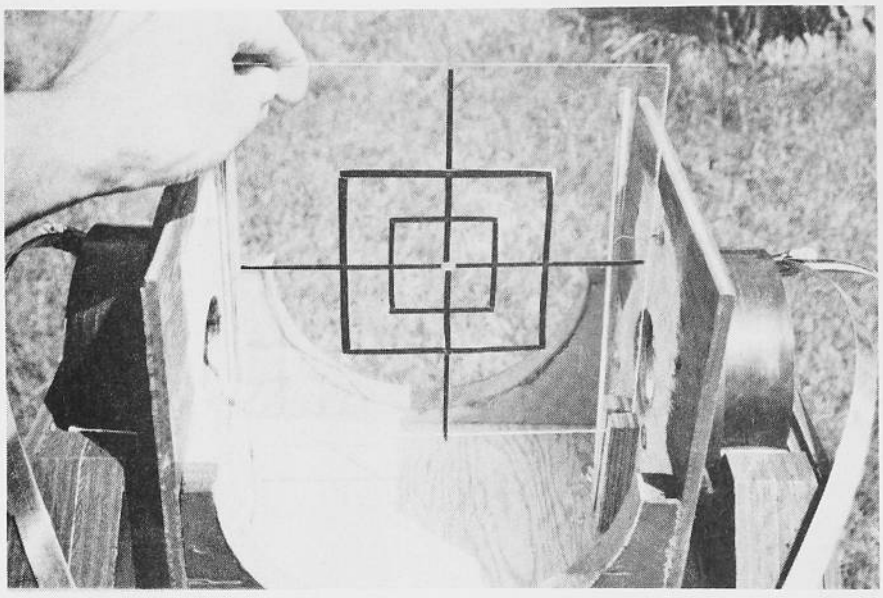
If you analyze the movement of the telescope, you will realize that the Dobsonian mount acts like a universal joint permitting the telescope to be oriented in any direction. This means the telescope can track equatorially because even though the mount is alt-azimuthal, its movement is restricted so it can only move in an equatorial fashion.

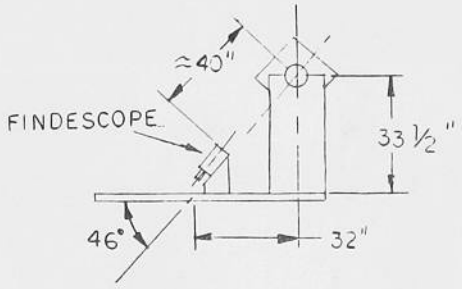
Design of the Base

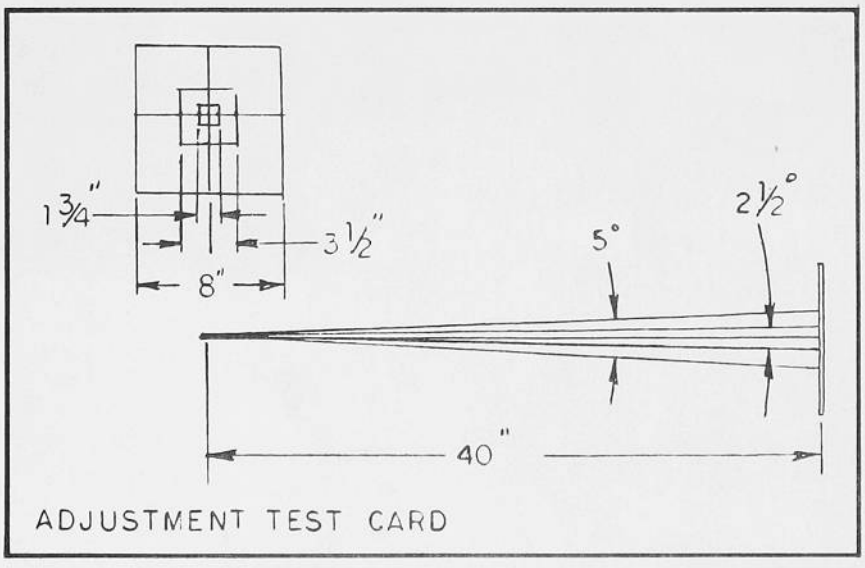
Everything rests on the base. Note that the base has three Teflon cushions holding the vertical axis. These are unusually high with respect to the bottom of the base. The reason is that at the beginning of my project, the azimuthal axis was supported by a bearing holding the system at that height. When I changed the system, I kept the base the same height because otherwise I would have been obliged to move the guiding arm — which I perferred to avoid! The best advice I can give you is to complete your base, and then place the supports with respect to the height of the telescope tube.

The polar arm supported on the base allows the lower end of the guiding arm to rotate around the polar axis; its upper surface defines the polar axis. This support is aligned with a finder telescope held in place by cloth straps. The support is attached to the base from below with screws. To help align the support while building it, I used small pieces of angle iron which I never removed.

To assure perfect guiding of the mount, the polar axis must point exactly at the north pole. I had to find a way to set the polar axis with sufficiently high precision. What I do now is shown very well in the pictures. To align the







mount, I installed an 8x50mm finderscope to the polar arm support, parallel to the polar axis. Then I installed a sighter made of Plexiglas at the intersection of the Dobsonian mount's axes, i.e., at the place occupied by the telescope tube, in order to align the whole system on the pole. The sighter has two squares inside each other which cover fields of 2.5° and 5°. It's very simple to build. To align the system on the north pole, I set Polaris at the center of the sighter by eye, and then do the fine adjustment using the finder in position.

Note that the dimensions in the drawings have been calculated for my 6" telescope at f/8. For other telescopes, these will vary. For my particular telescope, the polar axis intercepted the azimuthal axis at a height of 33½" above the base. The polar axis is adjusted for a latitude of 46°, but could be adjusted for any other latitudes in the neighborhood of 46° with the adjusting legs on the base.

Guiding Arm Design

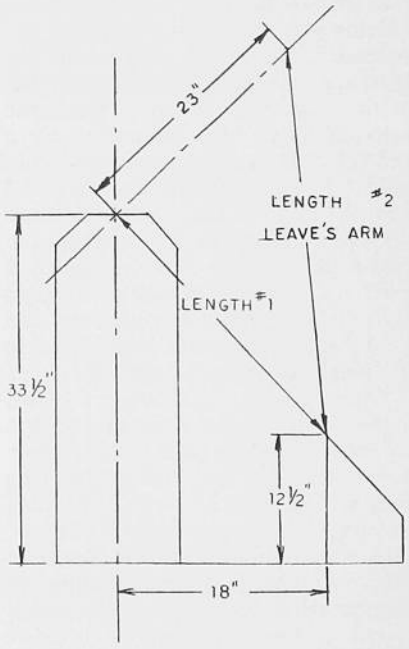
The guiding arm is the most important part of the guiding system. It turns around the polar axis, forcing the telescope to move equatorially. It's necessary to calculate the length of the arm in such a way that the telescope will follow the right trajectory. This is accomplished by considering the dimensions of the other components of the system.

However, I would like to direct your attention to balancing the tube. If the weight is heavier on the eyepiece side because of the collar, the motor will have to give supplementary power when the telescope points southeast (in addition to the power needed to overcome the friction on the Teflon support) and the mount will have a tendency to move faster when the telescope points southwest. In the same way, if the tube is heavier on the other side, the same problems will appear but reversed.

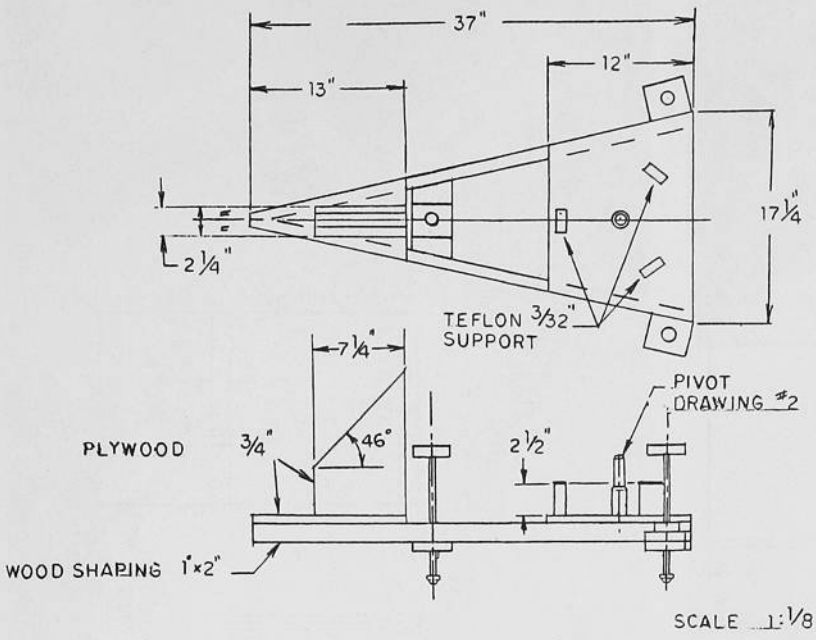
To find the arm length, I used the Pythagorean theorem to calculate the following equations for the dimensions of my mount:

$$\text{Axis length} = ((33.5 - 12.5)^2 + (18)^2)^{0.5} = 27.5$$

$$\text{Arm length} = ((27.5)^2 + (23)^2)^{0.5} = 35.7$$

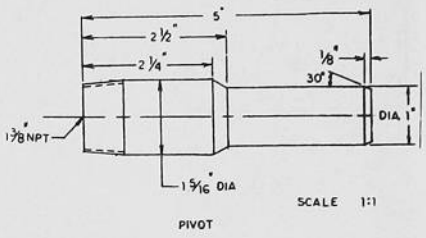


The arm length here is the length needed to point the telescope at the celestial equator. How long should it be to reach stars north and south of the celestial equator? I decided that 25°

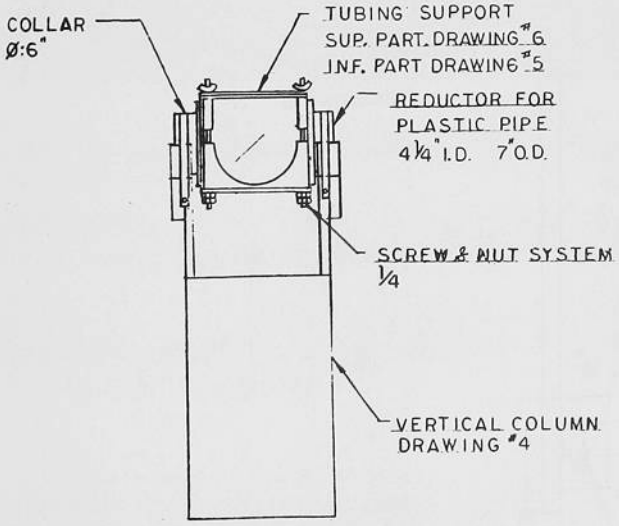


BASE OF THE MOUNTING

DRAWING #1

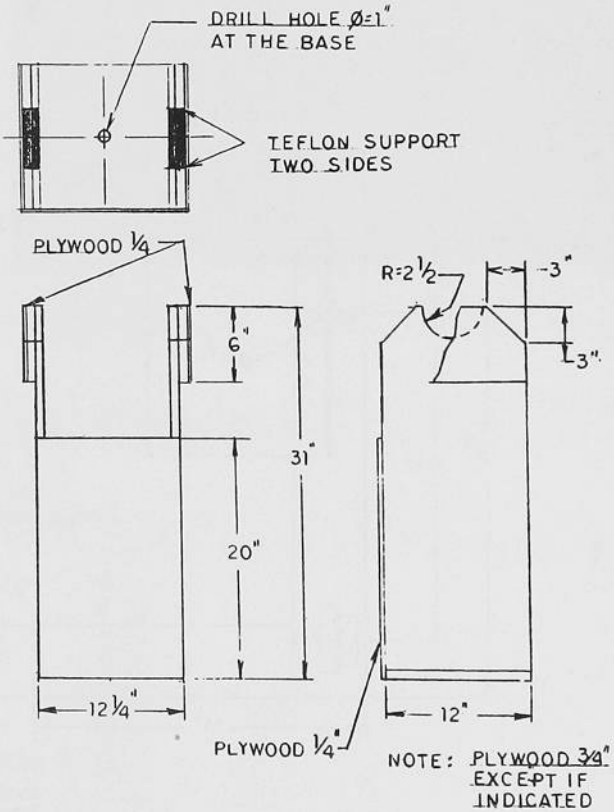


DRAWING #2



SUPERIOR PART OF THE MOUNTING

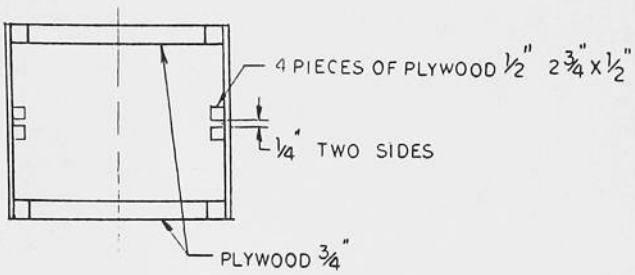
DRAWING #3

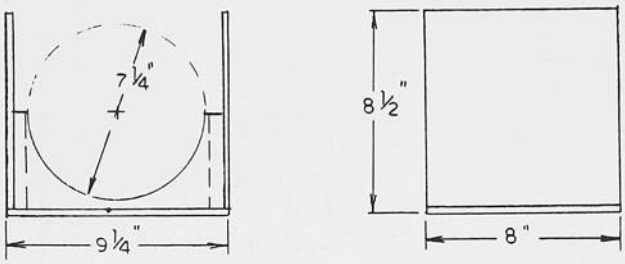


VERTICAL COLUMN

DRAWING #4

SCALE 1:1/4

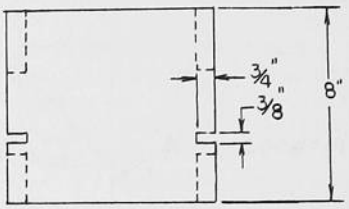


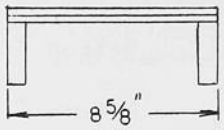


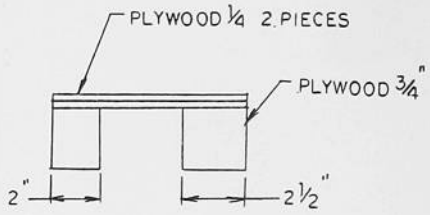
NOTE: PLYWOOD 1/4" EXCEPT IF INDICATED

INFERIOR PART

DRAWING #5

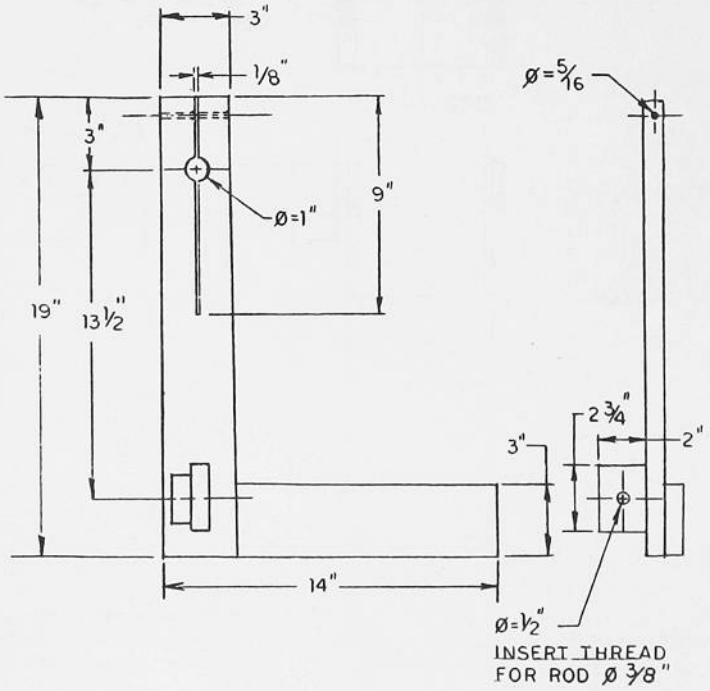






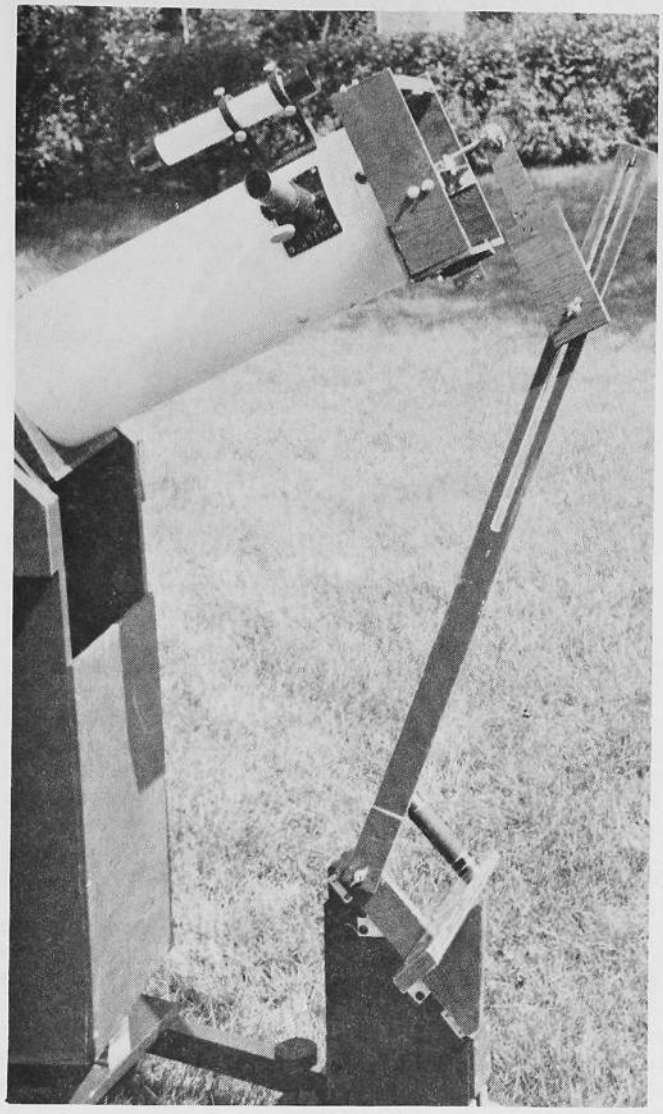
SUPERIOR PART

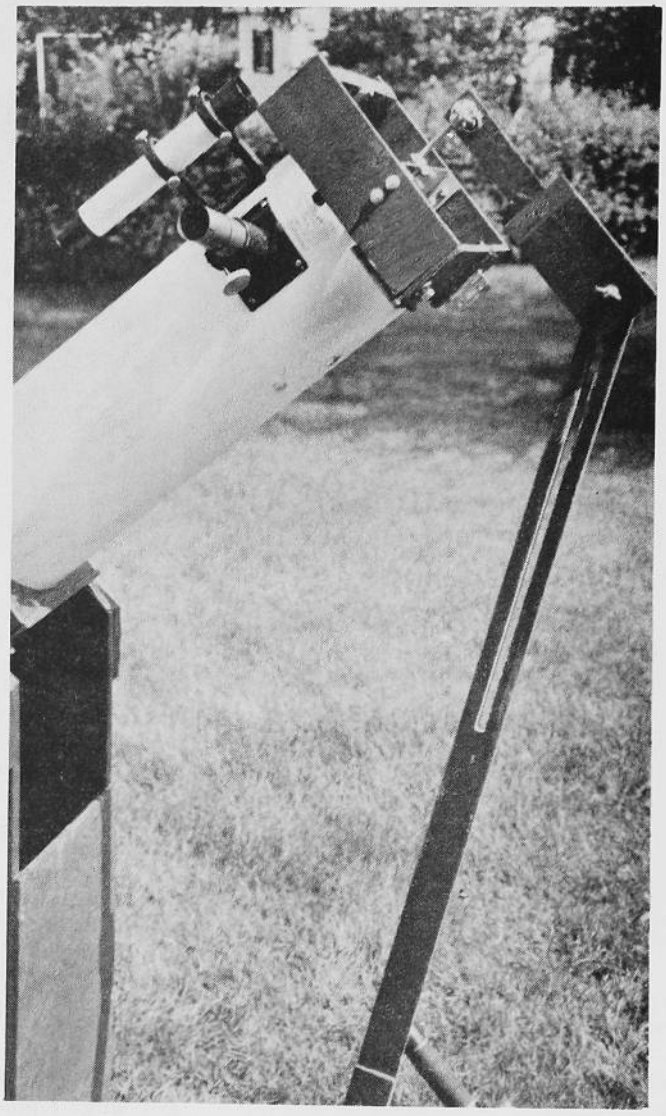
DRAWING #6



FIXE PART

DRAWING #7



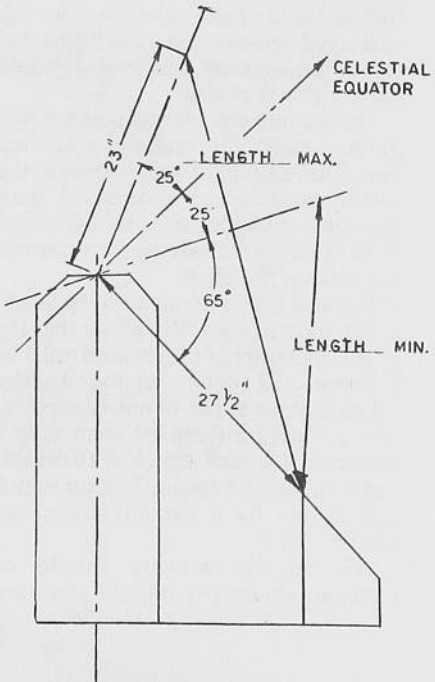


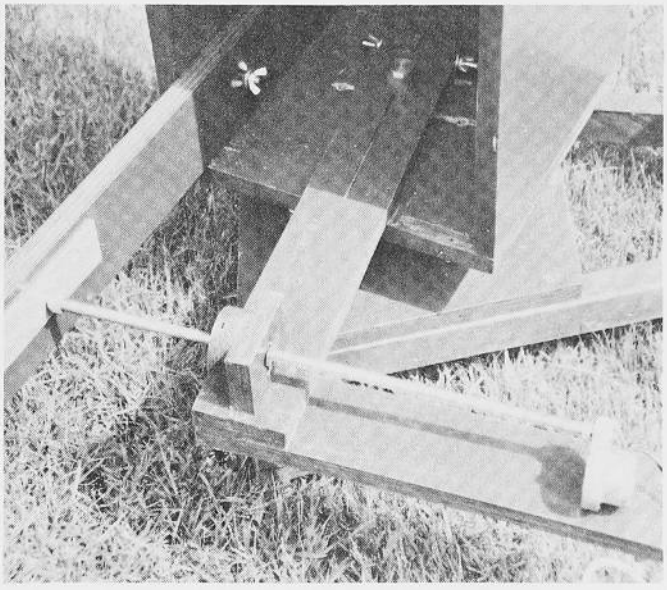
either side was enough, then calculated the lengths as follows:

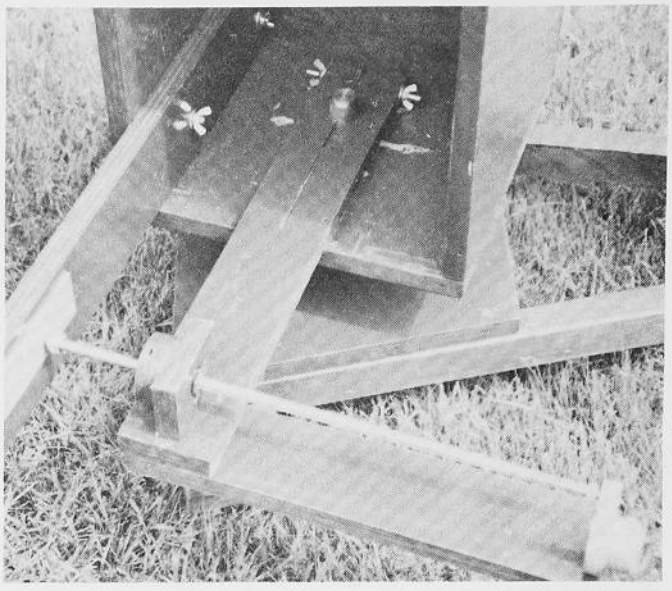
Max length = $(|23|^2$
$-2x23x27.5x\cos(25°+25°+65°)|)^{0.5}$
$= 42.5$

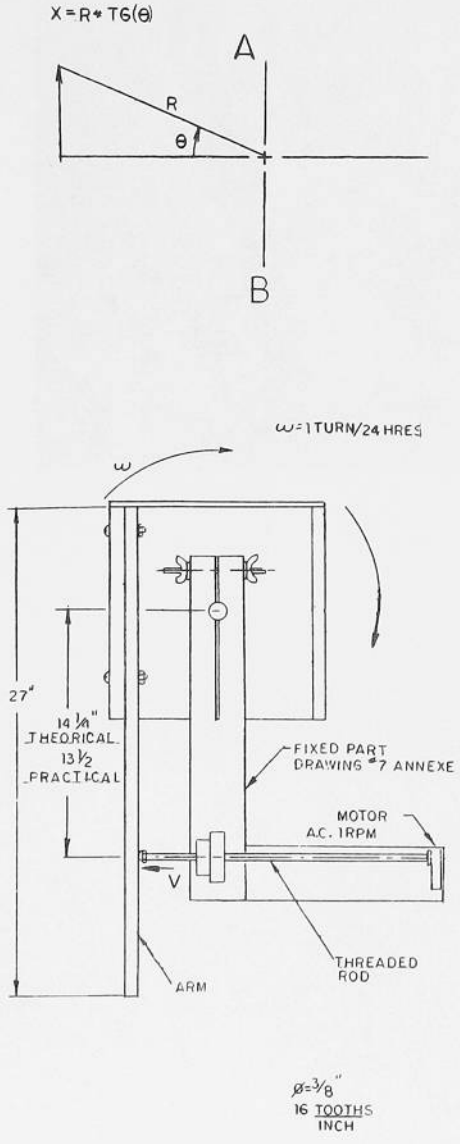
Min length = $(|23|^2$
$-2x23x27.5x\cos(65°)|)^{0.5}$
$= 27.5$

For the telescope to point at other parts of the sky, the arm must be longer or shorter. To permit declination change, I sawed a slot along the arm. A bolt slides in this slot to position the telescope. When the telescope is pointing to its lowest position (declination −25°), the upper part of the arm intercepts the telescope's field. When the telescope is used only as a guiding optical system, this is not important, but I would like to remove that problem eventually.









Adding a Clock Drive

To complete the description of my mount, I'm going to explain how I made its driving system. The mount is driven by the azimuthal axis and not by the arm. I mention this specifically because of numerous questions from other amateur astronomers.

In the beginning, I hoped I could use the same driving system used on an equatorial mount, but soon realized that the motor wasn't powerful enough. I could have invested in a worm gear system, but it's very expensive. So I had to find another way. I decided to build a driving system similar to the one used on an equatorial table.

The principle on which I started is the following: the azimuthal axis is the horizontal projection of the equatorial axis, which represents the movement of the stars. Over a 24-hour period, the two axes have the same average angular speed. Because the altitude axis is inclined to the polar axis, however, the rotational velocity about the azimuthal axis is not constant, but over a limited arc it's pretty close.

The azimuth drive is composed of two parts: a stationary one and a moving one. The stationary part supports the motor which drives a threaded shaft through a traveling nut on the azimuthal shaft. A slot in the moving piece permits it to clamp the shaft.

The next task is to calculate the length of the moving part. We know that the angular velocity of the column must be uniform and equal to the angular rotation of the Earth, or one turn per 24 hours. I used a threaded shaft with a diameter of ⅜" and a pitch of 16 threads per inch, and a 1 rpm AC motor which can be fed by a variable frequency power supply.

The angular velocity should be 0.00436 radians per minute (one turn per day). Since the motor advances the rod 0.0625" per minute, the radius of the arm should be 14.33". Thus, in principle, the rod screw should be positioned 14.33" from the pin of the base. I have obtained good driving with a distance 13.5" from the pin. This difference is caused by the projection of the polar axis on the azimuth axis making the drive rate non-uniform over a 24-hour period. As you can see, it's preferable to make a little guiding test to adjust your equipment.

It is quite possible that after you have attached the polar arm support to the base, you'll find that the polar axis doesn't intercept the altitude axis exactly. However, you can compensate by aligning the cock-eyed polar axis on the north pole using the adjustable legs on the base.

Conclusion

To finish, I can tell you that I am very satisfied and surprised with my results. When I wrote this article, I had succeeded in guiding on a star for 20 minutes. I am now working on some modifications of the design so that the tube of the telescope turns around its optical axis and I can attach a camera piggyback on the telescope.

If I have succeeded in giving you the inclination to build one yourself, I am very happy of that. If you have some ideas of your own that will improve it, I would be even happier. You are invited to write me your comments. I would appreciate that very much. I will produce a new article during the winter of 1985 where I will describe to you the latest modifications. I am waiting for news from interested amateurs.

Martin Rochette
1323 Jolliet Street
Chicoutimi
Quebec Province
Canada G7J 2R9

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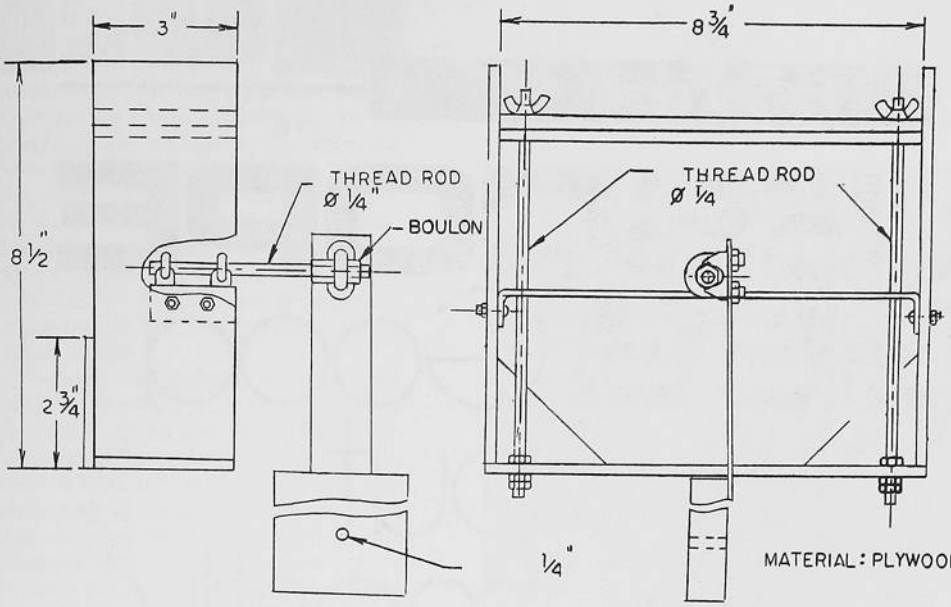
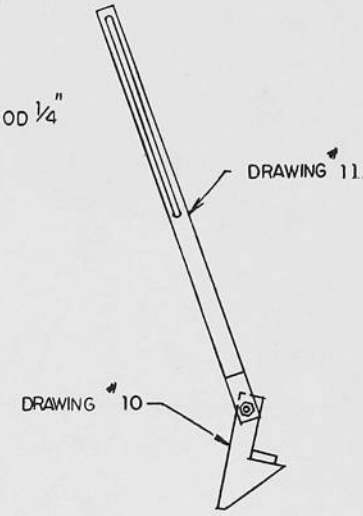
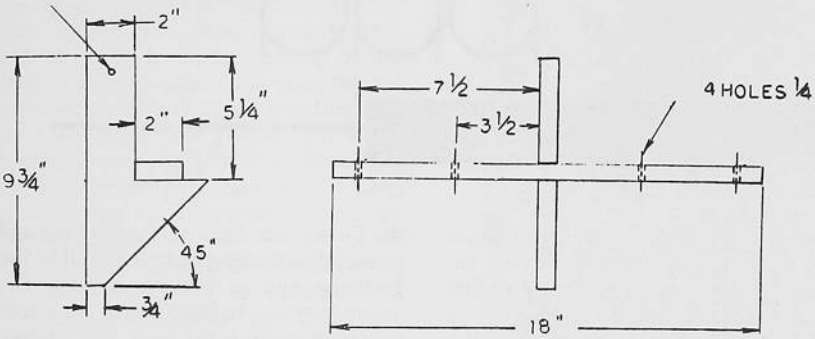


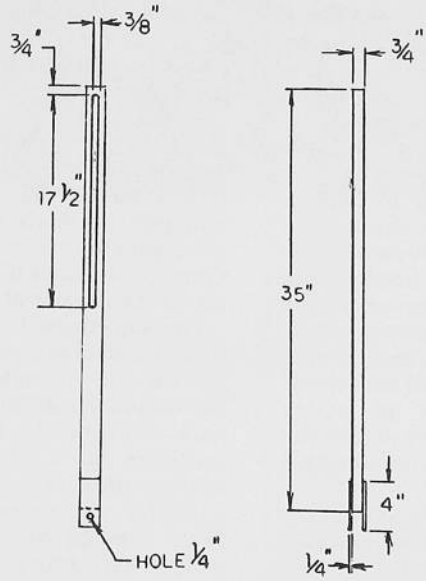


LEAVE'S ARM

DRAWING # 9



DRAWING # 10



DRAWING # 11

TELESCOPE TUBES Good but mostly bad

Many amateur telescopes, even those with the best of optics, perform poorly because of the tube or structure holding the optics. This is especially true of reflecting-type instruments. Since most optical systems are mounted in a tube, let us examine the good and bad points of telescope tubes.

First, what does the tube do? There are two prime requirements: it must be rigid enough to hold the optical components in alignment relative to one another so a proper image can be obtained. If the tube has a thin wall, then it should have reinforcing rings at the top and the bottom to prevent flexure and distortion of the tube in operation. These do not have to be fancy metal parts. Even simple wooden rings can make all the difference in the performance of an instrument. If we assume that the tube has met the first requirement, then the little understood second one becomes of prime importance: the emissivity of the tube material. What is emissivity and why is it so important?

In the study of physics, one learns that a black body is the best absorber of energy (heat); but likewise, it is also the best energy radiator. It is the second part of this statement that interests us. Radiant loss of heat from a body, in this case a tube, is called its emissivity. In a telescope tube, the higher the efficiency of its radiative loss, the quicker the instrument will stabilize.

Radiation is not the only heat loss mechanism. Surfaces can also lose heat by conduction and convection. This shows up as a layer of warm air near the surface. In a telescope, it can be disastrous. Our local group in New York City back in the 30s had a rule that all mirrors had to be in tubes at least two inches larger than the mirror to minimize this effect. Of course, warm air doesn't limit itself to the tube wall. Convection causes blobs of air to drift across the interior of the tube.

You sometimes hear the statement that a refractor is superior to a reflector because the refractor has no tube current problems. This is false, because both instruments have tube wall problems. But it often appears that a refractor presents a steadier image than a similar size reflecting instrument. Why? Suppose we compare the light paths in a refractor and a Cassegrain. In the Cassegrain, light enters the tube and passes down along the tube wall to the primary, and is then reflected to the secondary and to final focus. Note that the light passes through the surface turbulence.

In the refractor, light strikes the objective lens at the top of the tube and is refracted toward focus. Its path does not pass close to the tube wall and its disturbing influence. Part of the explanation of the superior performance of the refractor is this difference in the light paths.

Lenses are less sensitive to temperature differences than mirror optics, but this same problem occurs even when the mirrors are made of zero expansion glass-ceramic material; thermal changes in the optics are the lesser of the two evils in this situation.

If the walls of a tube are far enough away from the light path, then images will improve while the instrument is becoming stabilized to temperature. However, the oversize tube is harder to handle and it costs more.

One way to handle tube wall currents is to eliminate them entirely with an open tube structure. This, at first glance,

seems ideal, but nothing is free. While eliminating wall thermals, other problems are brought to the fore. An open structure must maintain optical alignment, just as a solid tube must. With careful design, this can be done. The usual solution is a truss, which eliminates weight, yet holds alignment well. Many examples and descriptions of this type of tube can be found in back issues of *TM*.

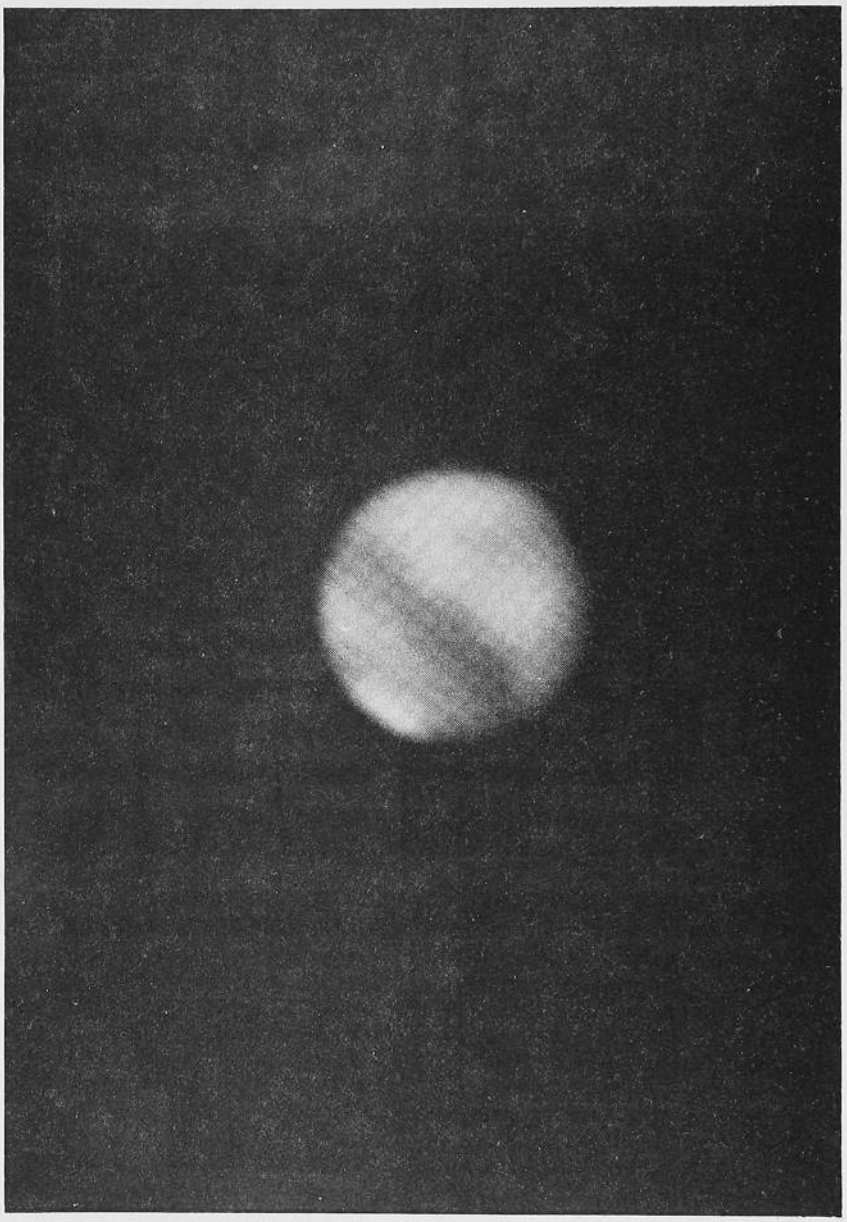
The next big problem with an open tube is that air currents can pass through the tube and the optical path. One important consideration is that such a tube be rotatable so you can always bring the eyepiece to a position that flowing air comes through the telescope before it reaches the observer. If this is not done, then your own body heat will be carried across the optical path to really foul up the image.

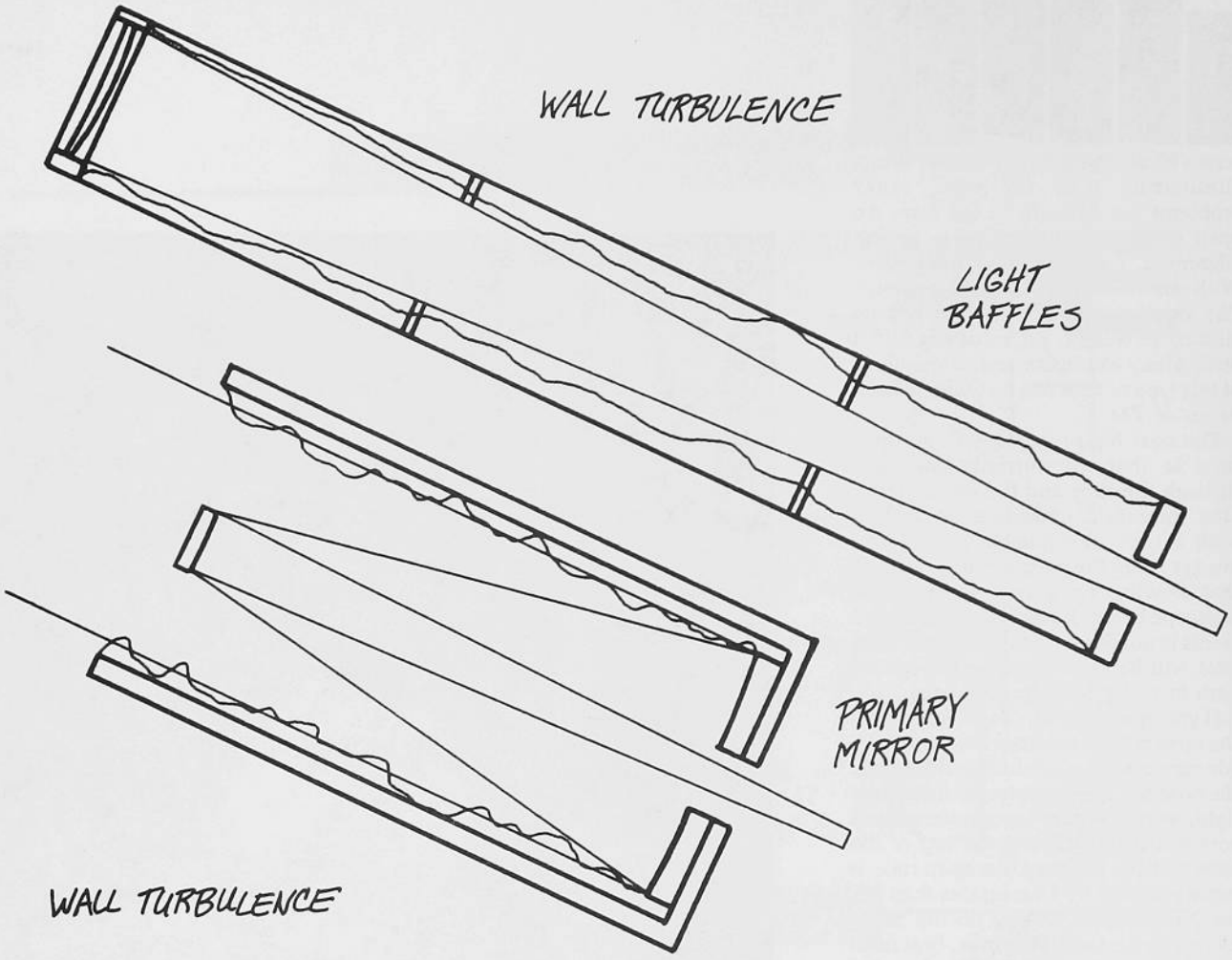
If you operate in an observatory, then the open type of tube has less problems. Air currents are sometimes reduced and the observer is also protected from stray light, which otherwise requires some sort of baffling around the top of the tube and the primary. An open tube is more practical for Cassegrains than it is for Newtonians, as you do not stand alongside the tube. However, heat from the observer may still rise into the tube, so the rear of the tube should be properly sealed.

If you wish to determine the best type of tube material for an astronomical telescope, then look for high emissivity. Although it is true that a "perfect" black body would be the ideal material, we don't have such tube material available. Because heat energy takes time to traverse a material, we must also consider the conductivity of the material involved.

Not to change the subject, but what are two reasons you paint the outside of a home? Obviously you want to make it look better, and you do the same for a telescope. However, an important second reason is to insulate the house. Even though it is a small effect, paint *does* help insulate a house. But if this is true, then it also insulates a telescope tube and inhibits the emissivity!

Quite often amateurs use material that has acceptable emissivity, and then, without realizing it, alter its efficiency or conductivity by adding materials to it such as paint, vinyl, etc. This applies to black paint, as its conductivity is slower than plain metal — if the tube is made of this material, which we will assume it is for this discussion.





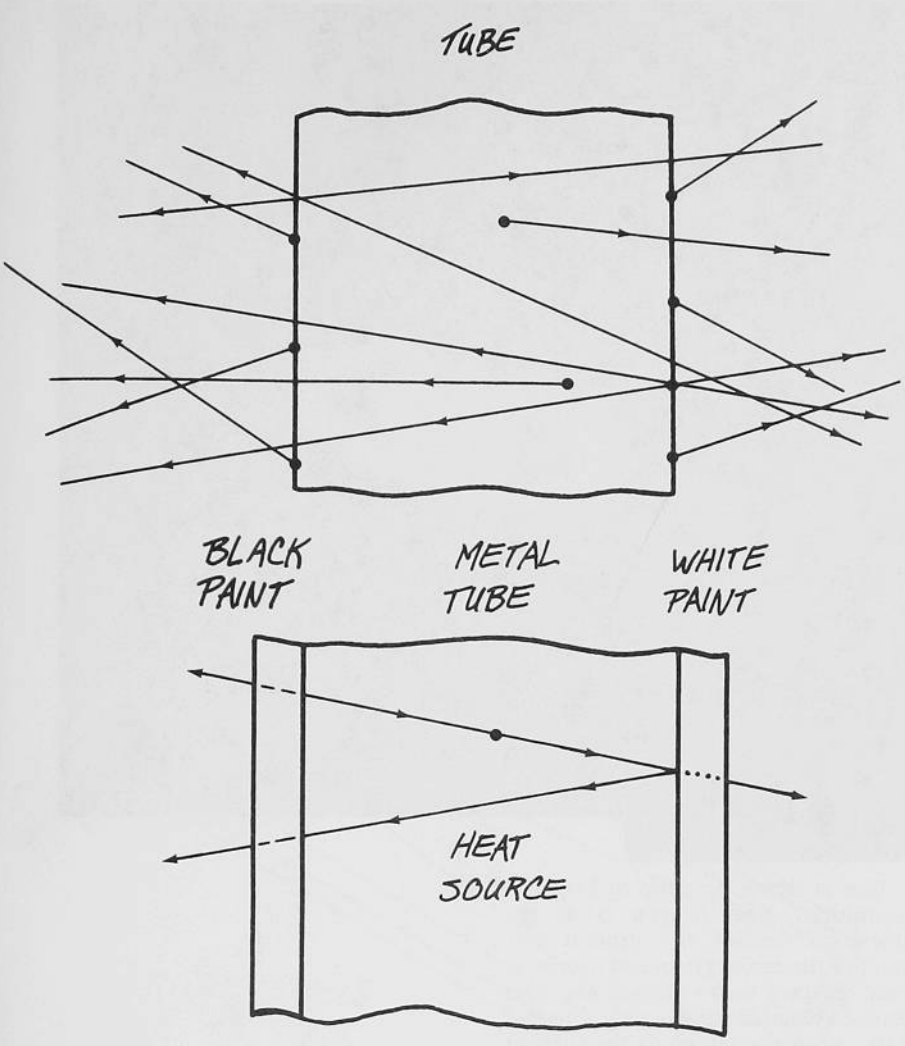
Imagine the cross section of a metal tube that is painted black on the inside and white on the outside. The paint obviously helps prevent light reflected from the walls from reaching the main mirror. Suppose now, for our discussion, that the tube has been in a warm home and is taken out on a cool evening for observing. What is the flow of heat from the metal under these conditions? On the inside of the tube, the flow is through the black paint, and being black, it has the highest emissivity of any color of paint, radiating heat rapidly. Unfortunately though, this loss is *inside* the tube, and so contributes to the wall air turbulance.

Now consider the outside of the tube. What happens there? Well, it's painted white, right? White happens to be considered "scientific." After all, microscopes and other laboratory instruments are often white. But we are not using our telescope in a laboratory, so it is not necessary that they appear sterile! Well, you say, the real reason is that white has a high reflectivity and slows the absorption of heat into the tube. According to this, I have just justified painting all tubes white on the outside — right? Wrong!

Asking what appears to be perhaps a silly question, what is the color of the white paint on its *inside* surface — where it contacts the tube? It is white. So it reflects the heat trying to escape outward from the tube wall back into the interior of the telescope tube.

Because of this, white is the worst color on a telescope. But you say you want to keep the tube from absorbing heat if possible. Okay, but not at the expense of preventing it from equilibrating with the outside air. You would be better off allowing a tube to absorb heat with a black tube because it will also lose this heat more quickly.

Incidentally, another argument against white tubes is that they interfere with observing, especially with Newtonians. A good observer keeps both eyes open. If the tube is white, then the eye not looking through the eyepiece sees a white surface. Finally,



although I cannot prove it, at the many star parties I have attended in the summer, I've noticed mosquitoes seem to be attracted to white tubes!

Although more prevalent in years past, many astronomers still line their tube interiors with a layer of cork. This insulative material helps, in that the energy trying to reach the interior of the tube is blocked and is instead radiated at the outside wall. Although not a complete cure, it helps to some extent.

Some years ago, I had a letter from Rochester, New York. The writer mentioned that many amateurs were mounting their reflectors in plain, unpainted black iron tubes and getting excellent results with temperature stabilization and seeing. From what we have discussed up to this point, it would appear that a dark, highly conductive material is one of the best you could use.

Another problem is observing on a night with a breeze. When you point the tube into the breeze, air entering the tube causes currents and disrupts seeing. Why not close the tube with a window? If this is done, we have the classic case of "good news and bad news." The good news is that air is prevented from entering an open-end tube and causing air currents. The bad news is that sealing a tube may cause more trouble than it prevents.

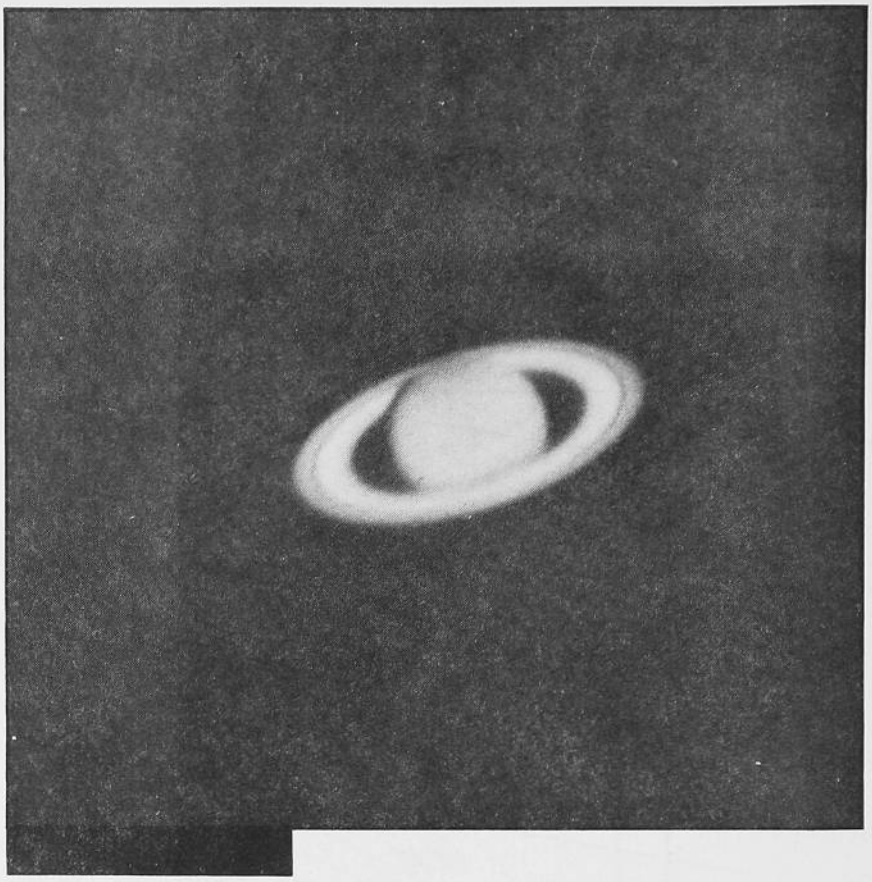
At the beginning of the 70s, and for some time thereafter, some of the finest Moon and planet photographs were being done by E. Ken Owen of Oklahoma City. His instrument was professionally made, and in the laboratory residual aberrations of the system as a whole tested to $\frac{1}{25}$-wave. His telescope was a Newtonian with a 10" f/6.1 paraboloidal primary, diagonal flat, and optical window at its upper end. This sealed the tube and also supported the flat, incidentally, eliminating spider diffraction. The instrument was kept outdoors in an observatory structure that lifted off when the unit was in operation.

Despite all this, its performance was disappointing. Owen reported that the telescope either took too long to settle down or seemed to never settle down at all. Indications were that the sealed tube was the culprit, despite all he had read about the advantages of windows. Throwing past suggestions to the wind, he cut slots in the cell at the top of the tube holding the window and immediately he found the system performed to expectations.

Amateurs in the Rochester areas experienced a similar problem assembling an 11" Maksutov. They, too, found it necessary to vent the formerly sealed tube of the large Newtonian instrument. Why were these large instruments unable to operate as a sealed system? What destroyed definition?

The major problem is that a sealed system acts as its own little world. As in Earth's closed environment, warm air rises and cold air settles in a closed telescope tube. With the tube pointed toward the zenith, air stagnates into layers of hot and cold, with the hot on top. Light passing into the system does so equally throughout the air column, and over so short a path, the temperature differences are not too detrimental. When the tube is pointed at an angle, the light at the top of the tube passes totally, or almost so, through warm air which has risen to the top of the tube, while light at the lower section passes through cold air. The two different environments for the light path destroy good definition, since there is no way wavefronts from both areas can work together to form a good image.

Is there any way a sealed system could work? It seems an excellent way to go if proper operation can be obtained. After all, a sealed environment implies that you can control the environment, particularly any temperature effects. Air is a poor atmosphere for the interior of a sealed tube, in particular if it is not homogeneous — temperatures can vary widely throughout it, as anyone who as used the Foucault test in a drafty basement knows. If it were homogeneous and inert, then observing would be very different. Back in 1956, in the June *S&T*, H. Selby described a special type of telescope he had developed. Not only was there a window, but the eyepiece opening was also windowed. Dry inert gas filled the tube interior, at a slight positive pressure to insure it remained pure. Dr. James G. Baker, well-known designer of astronomical optics, has



recommended dry nitrogen for the gas. Since it is inert and homogeneous, temperature differences are minimized. If you want to use a window and obtain the highest efficiency of operation, then the inert gas-filled tube interior is the way to go.

But wait! What is this unruly mob that is about to descend on me crying for my scalp? I hear the words "Maksutov" and "Schmidt-Cassegrain" coming from them, amid cries that they, too, have sealed systems. Before I get lynched, let's examine these type of telescopes, today so prevalent among amateurs.

First since only the top end is sealed in these telescopes, you do not have a sealed system. Only if you always keep the zenith prism on, and it fits tightly into its opening, does it approach being sealed. Second, the light path down the tube, after passing through the corrector, passes along the inside of the tube, so you run the risk of tube wall currents. The owners of such systems can obviously ask, "Why don't I see the same air patterns of a Newtonian or Cassegrain?" The answer is: "Because the length of tube the incoming light encounters in Maks and SCTs is short."

I have one of the first mass-produced SCTs. I soon noticed that if the tripod and telescope were assembled indoors and taken out, that seeing was initially good (when upper air conditions were good), but within a few minutes performance deteriorated. After an interval, depending on how cold it was, the seeing once again became good. This was the internal tube air finally reaching stabilization with outside conditions, just like any other telescope used under similar conditions. The SCT has an additional problem caused by the holder for the secondary and the internal baffling, which the Maksutov, with its aluminized spot for the secondary, does not. If you point a SCT toward a bright star and draw the eyepiece out of focus when starting to observe, you will see a plume of heat rising from the secondary support and internal baffle. The effect continues until stabilization of these parts with surrounding air temperature takes place.

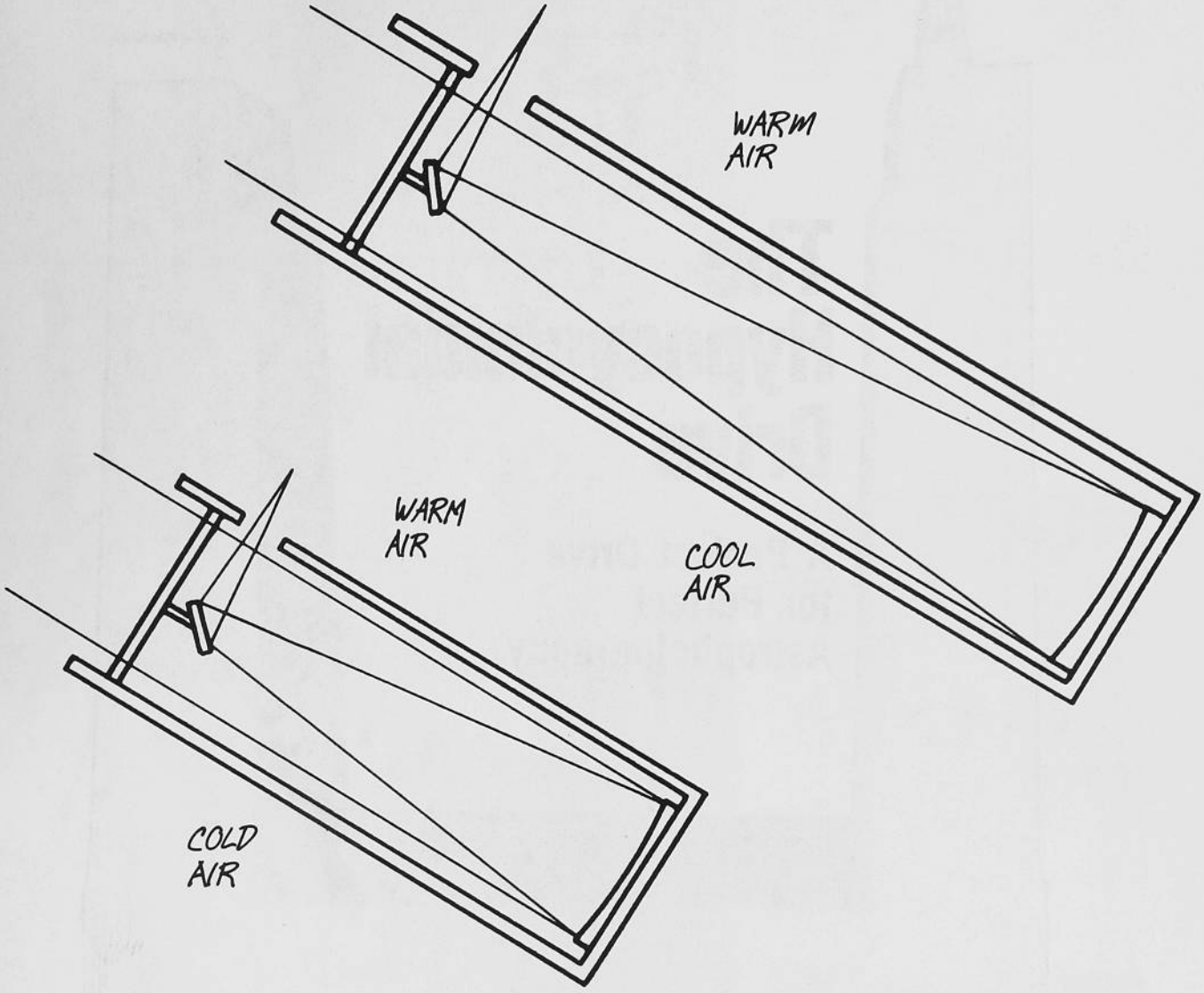
Can anything be done to help this condition? Yes. If you point the telescope toward the ground and remove the zenith prism and eyepiece, then internal warm air will rise and escape. Granted, this is only a partial help, since the warm air that cannot pass through the internal baffle will be trapped around the primary mirror. You could probably further help minimize this effect of trapped air by every so often pointing the tube toward the zenith for a few minutes and then returning it to its former position so more air can rise toward the eyepiece opening.

One advantage of 50 years in telescope making is you see many good and bad ideas. When I started in this hobby back in the early 30s, many tubes had a door at the back end, just above the mirror. It served several purposes. It enabled you to reach the mirror surface to blow or gently brush off dirt particles that had settled on it. It also allowed you to cover the mirror, and, as further protection for the silvering, to place bags of dry rice grains around the mirror or in its cover to absorb moisture. Today we have silica gel for this purpose. Incidentally, at today's high prices for coating mirrors, putting a cover directly over the primary mirror to extend its life is worthwhile.

Another use of the door was for ventilation. Opening the door helped cool the tube quickly. Before observations were begun, an electric fan could be used to blow air up the tube. The final thermal stabilization of the assembly, with the door closed, was much quicker if the warm air was forced out early.

With my own Newtonian reflectors, I always point the mirror cell toward prevailing breezes and allow them to pass around the mirror and up the tube to exit at the top, which is the same as using a fan, but slower. Don't point the open end toward the moving air, as this deposits dust and dirt on the face of the primary mirror.

Some years ago, an amateur with a 16″ Newtonian used for planetary observations had a novel approach to eliminate tube effects. To help cool the tube, he attached a plastic sleeve around the mirror end of his instrument to a



hose attached to a vacuum cleaner. He claimed that this system allowed him to see and draw more planetary detail than he could without it, once a gentle laminar flow of air had been achieved. Incidentally, he reduced the speed of the vacuum motor with a variac, and the plastic sleeve was loose enough that no vibrations from the vacuum were transmitted to the telescope.

Although on large tubes it would be an expensive approach, for small telescopes, black anodized aluminum tubes should be good. Immediately after anodizing, the oxide coating is porous. To color it, the piece is immersed in dye. The surface absorbs a thin layer of this dye, which is made permanent by sealing the surface in boiling water or an oven. Although we have altered the surface of the metal, the dye layer is so thin compared to a similar painted surface that the emissivity should remain high. At this time, I would venture that his type of tube for a Maksutov or SCT is an ideal one, and would be glad to hear from anyone who has tried it.

Unfortunately, it appears that we must have a structure to hold the optics of a telescope, and the simplest is some sort of tube. If you are willing to accept the expense of sealing and machining a tube and optics supports airtight, then the solution with the greatest potential is the sealed tube with an inert dry gas filling the interior of the tube, with a small positive pressure to assure that no air leaks in.

There are many materials used for telescope tubes — metal, plastic, paper, wood, just to name a few. It would be both valuable and interesting if someone were to conduct experiments on the absorption and emissivity of various materials in their natural and painted states, and also with surfaces altered by paint, fiberglass, paper, and vinyl. Perhaps an interested reader with laboratory measuring devices will perform such experiments and report them in *TM* so that instead of guesses, we will have actual results. A physics professor or student looking for a subject for a term paper in physics could do this, especially if they have an interest in astronomy and the time to experiment.

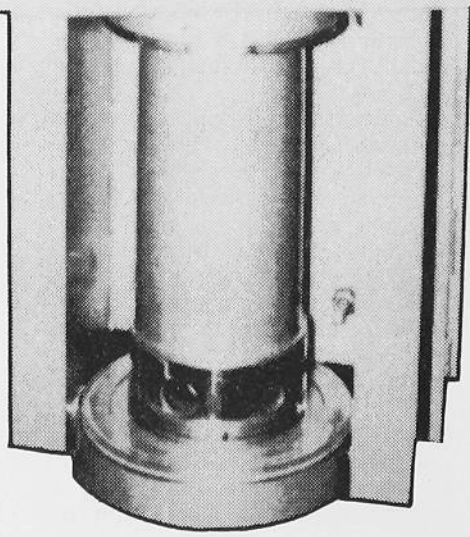
— Robert E. Cox

■

— For further discussion of tube currents and tube windows by another experienced telescope builder and user, readers should also refer to the second American edition of How To Make a Telescope, *by Jean Texereau.*

The Hypocycloidal Drive

A Perfect Drive for Perfect Astrophotography

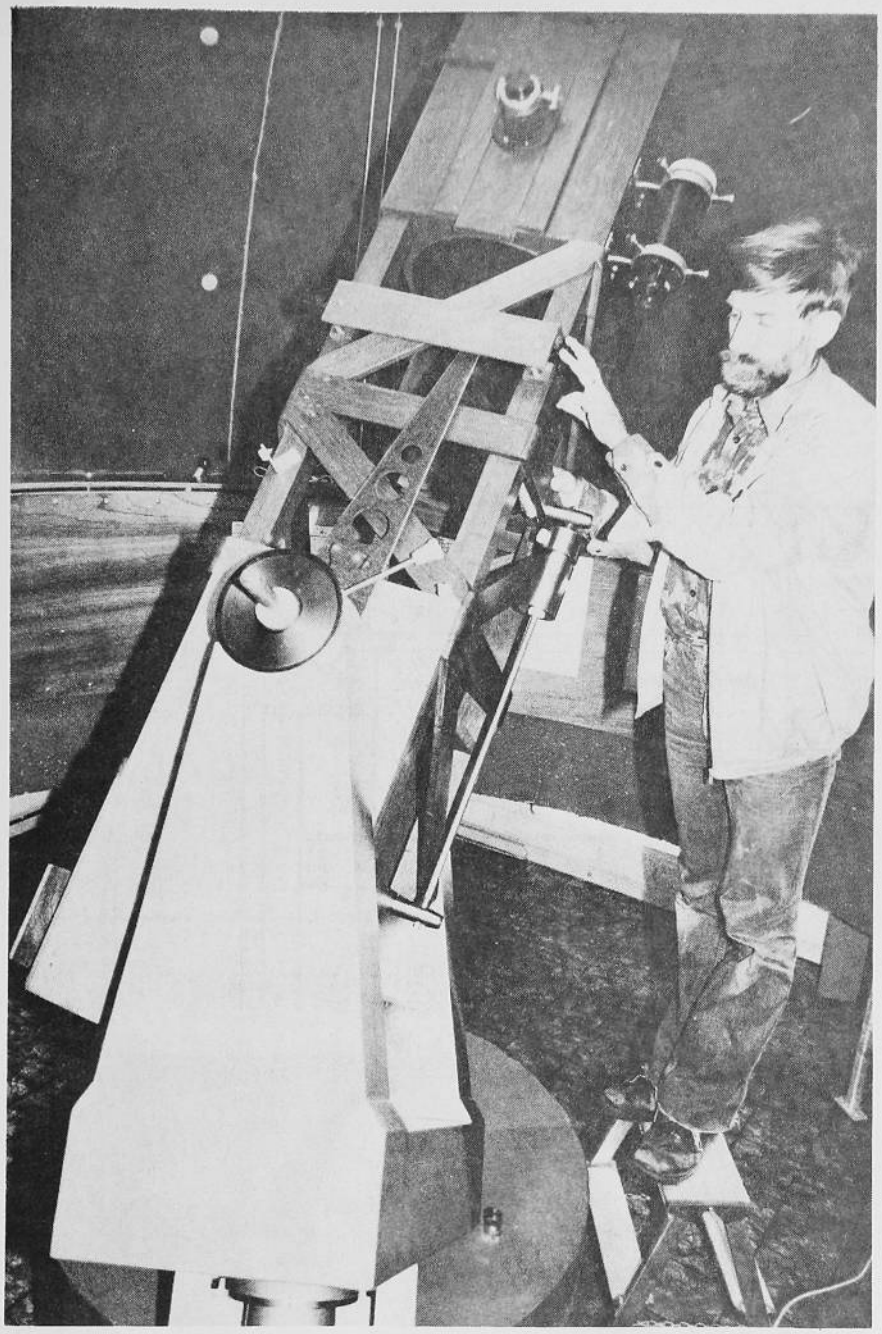


Although many kinds of telescope drives have been built, we've never heard of anything like the differential hypocycloidal drive on our 39cm Newtonian reflector. We're pleased to be the first to apply the principle to a telescope, and we're equally pleased to announce to the world that it works very well.

The hypocycloidal drive principle is, in fact, very old. We have seen examples of it in museums. When a study of the drive and its principle of operation, done by a senior member of our society, showed it would drive a telescope with exceptional smoothness, we decided to try it.

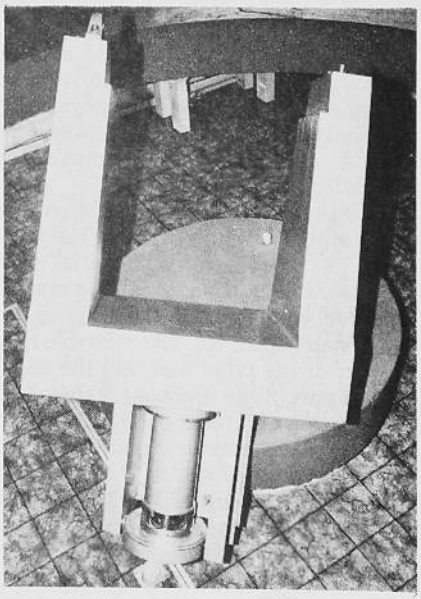
We pooled our ideas and after two years, the working drive was done. Our initial test made in 1984 revealed that only one part had to be changed. Now the system works as it should, and six months later, we can report that no further problems have appeared. This drive can be made at home by any amateur, even though some parts require machining on a lathe; this work could be farmed out.

The hypocycloidal drive has a very large speed reduction in one direct step. The principle of the drive is a little hard to grasp at first but once you understand it, it seems obvious. Consider a disk (outside diameter B) rotating against a ring (inside diameter A). The diameter of the disk is only slightly smaller than



The second author shown standing beside the newly-completed 39cm f/5 Newtonian telescope. The telescope's tube is an open wooden framework. Mr. Simons is the observatory chairman; Mr. v. Haasteren designed and constructed the drive.

The parts of the drive shown just before mounting and testing.



The massive base, fork mounting, polar shaft, and hypocycloidal drive. The base is made of concrete and the fork is wood.

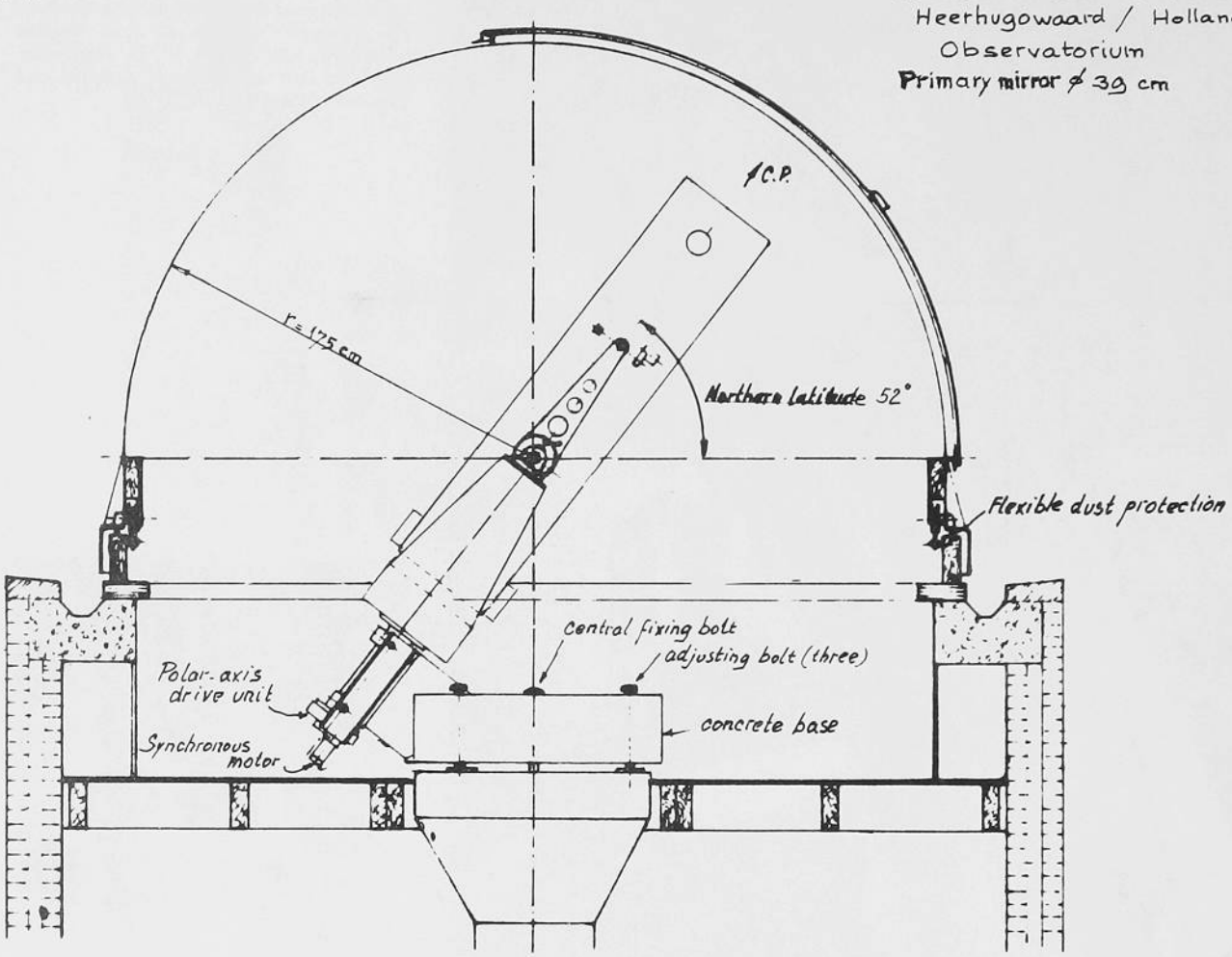
ne diameter of the ring (i.e., B is slightly less than A).

Now, suppose that the ring can't rotate, and that the disk is pushed against the inside diameter of the ring by an eccentric shaft mechanism. If the shaft rotates, the disk will rotate around its center in the opposite direction, rolling around the inside diameter A. Moreover, the center of the disk will trace a small circle. The radius of this circle is equal to half of the difference between the diameters A and B. The path that any point on the radius of the disk follows when a circle rolls inside a fixed circle without slipping is called a hypocycloid.

If, on the other hand, the disk is prevented from rotating about its center (so only its circular movement remains), but the ring is allowed to move freely, the ring will start rotating in the same direction as the eccentric shaft. This second case we see with diameters C and D of the disk and ring.

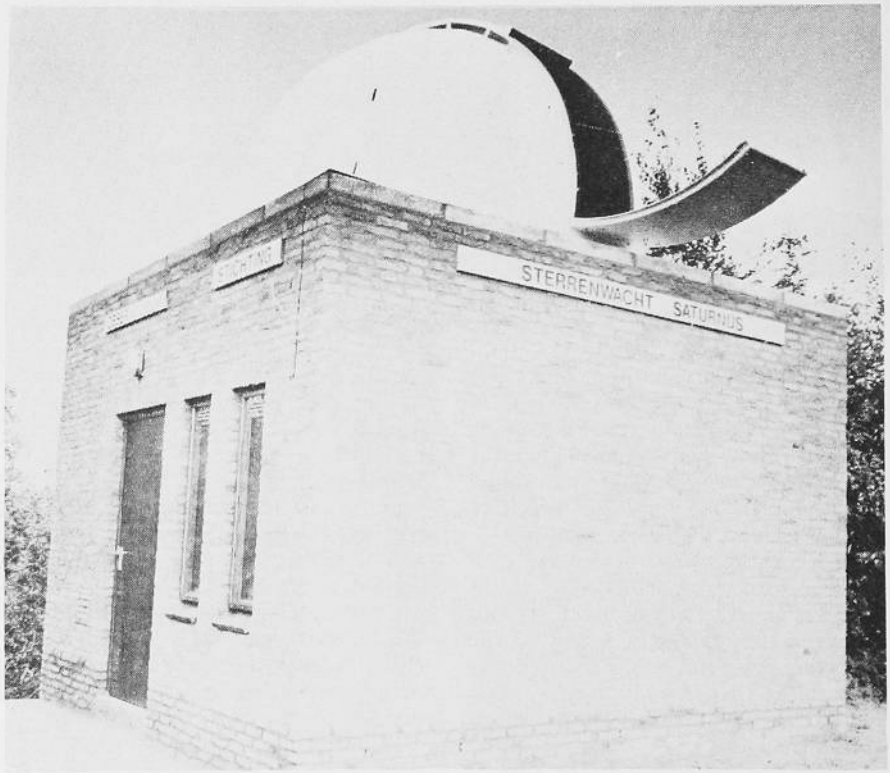
In the first case, the speed reduction between the central axis and the disk is equal to the difference between the diameters of the disk and the ring divided by the disk's diameter. In the second case, the speed reduction is equal to the difference between the diameters of the ring and the disk divided by the ring's diameter.

When two such systems are combined, i.e., a disk with diameter B



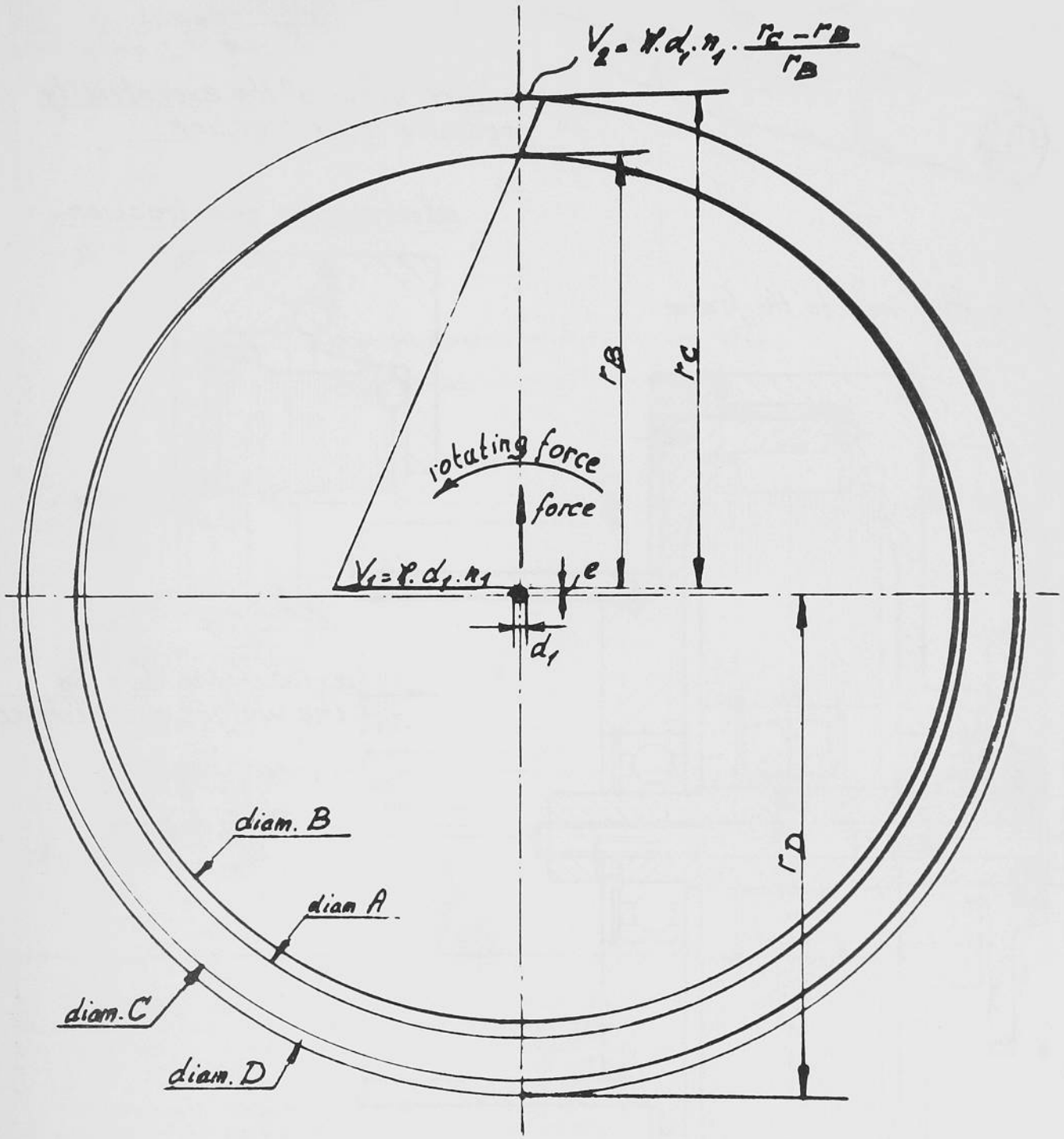
is connected to a ring having diameter C, a large speed reduction can be obtained providing there is a difference between the diameters of the first ring and disk and the second ring and disk. The first ring is fixed and the second ring is free to rotate. Such a combination is called a differential hypocycloidal transmission. (It helps to study the vector diagram and accompanying formulae.)

Our polar axis drive is based on this principle. The joined disk is made of hard phenol-type fabric material. The disk is pushed with a large force against the steel rings, which, of course, must have stable bearings. The rotatable ring is part of the polar axis and the fixed ring is part of the telescope frame. The mechanism for pressing the disk against the rings is an eccentric shaft built into the polar axis and driven at 1 r.p.m. (in our case) by means of a spur gear and synchronous motor. Careful study of



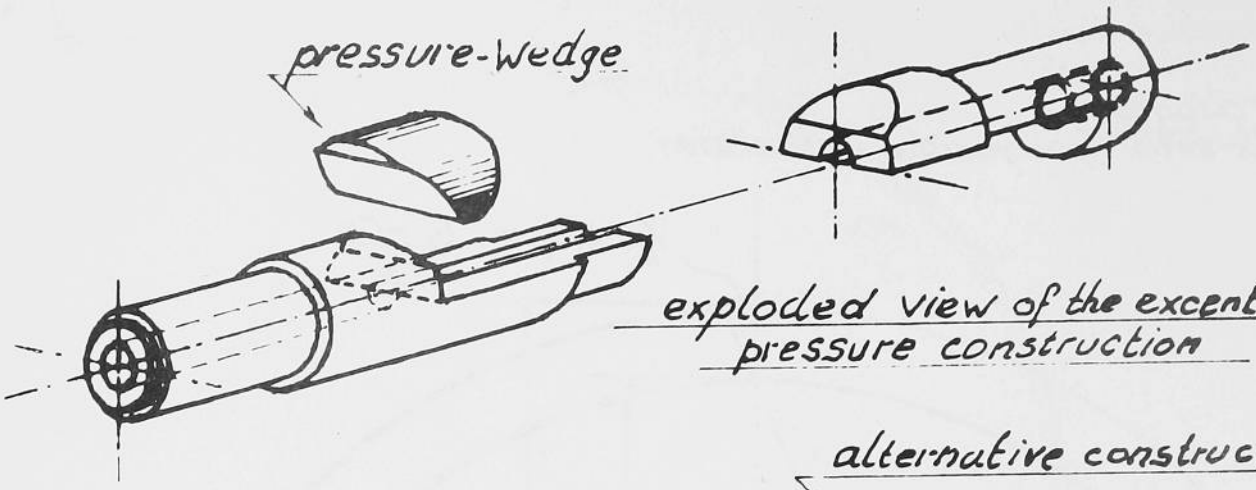
The newly-built Saturn Public Observatory (Volksterrenwacht Saturnus) boasts a 39cm Newtonian reflector. It is situated atop a hill in a park away from city streetlights.

Vector diagram of a Differential Hypocycloïdal Transmission



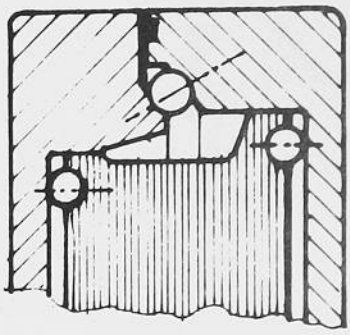
e = excentricity
d_1 = difference between discs and rings

$$\frac{n}{2} = \frac{V_2}{2\pi . r_D}$$
$$= \frac{\pi . d_1 . n_1 (r_C - r_B)}{2\pi . r_D . r_B}$$
$$= n_1 . \frac{d_1 . (r_C - r_B)}{2 r_D . r_B}$$

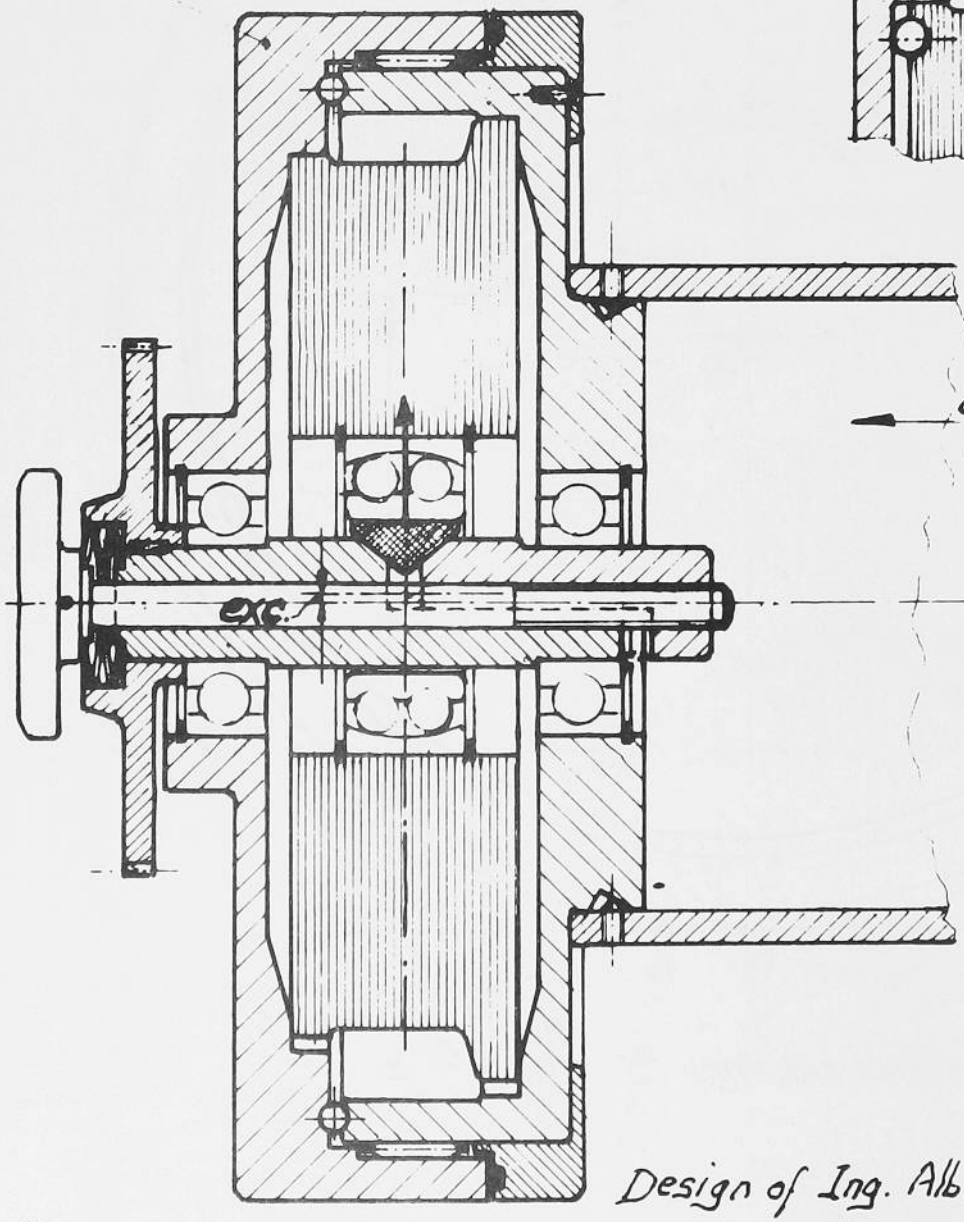


exploded view of the excentricity pressure construction

alternative construction



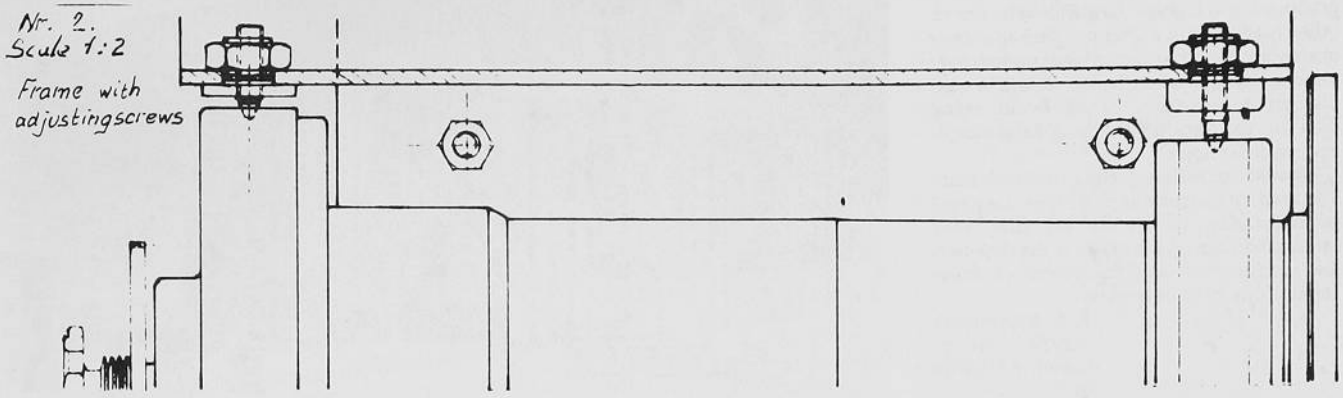
Ring A fixed to the frame

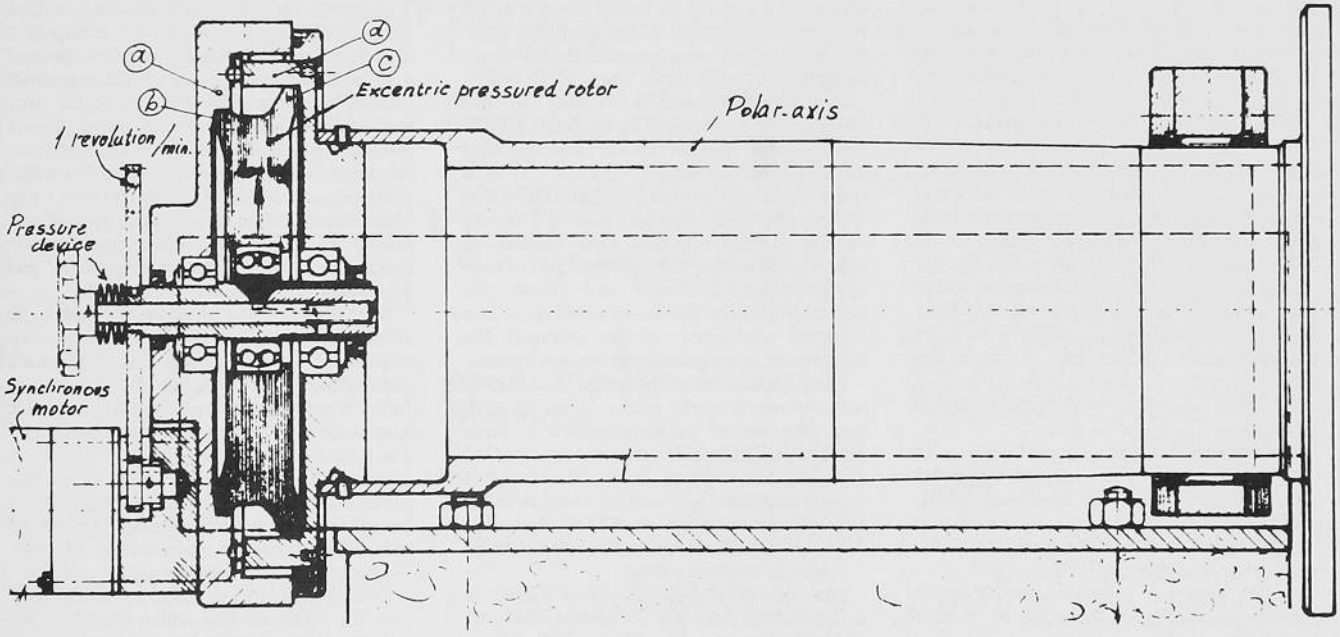


axial force due to the weight of the telescope

Polar axis

Design of Ing. Alb. v. Haasteren - Alkmaar





the drawings and photographs should answer many questions. The system also has an electronic drive corrector plus a dual axis automatic tracking system.

At Volksterrenwacht "Saturnus," a microcomputer is in use, too. The dome is computer-controlled, as is the telescope's speed. We also have the ability to couple a video camera to the telescope, and can transmit the signals to our clubhouse. It shows a nice picture on three TV screens.

Further information can be obtained from the author upon request, or by writing to Stichting Sterrenwacht "Saturnus" observatory. The observatory's address is:

Stichting Sterrenwacht "Saturnus"
Frans Hallsstrat 4
1701 JL Heerhugowaard
Holland
Telephone: Holland 02207-17323.

We hope that the mechanical drawings included in this article will help other amateurs interested in building this extremely smooth drive.

Alb. v. Haasteren and C. Simons
Wielingenweg 304
1826 BW Alkmaar
Holland
■

Letters

◄ 3

produced by a high-performance refractor or other high-quality objective. Perhaps some observers would prefer to give up extreme viewing angles in order to obtain a less expensive eyepiece, or to avoid using oversize focusers for the long focal length eyepiece versions.

I would appreciate getting feedback from TM readers concerning their size, cost, and performance priorities so that this information can be passed on to the designers and prospective manufacturers of these remarkable new eyepieces.

R.A. Buchroeder
2939 E. 3rd St.
Tucson, AZ 85716

WAA Gives Scopes

Dear Sir / In January 1983, the Western Amateur Astronomers, Astronomical Association of Northern California, and Telescope Makers Workshop-Chabot Observatory sent a 12.5″ Newtonian telescope to the Phillippine Astronomical Society as a gift. This was the first effort by the WAA to send telescope equipment to other countries in need of this material.

At the 1984 summer board meeting of the WAA, a third world committee was set up. This committee is responsible for setting up a service to help send equipment to these countries, as a clearing-house between third-world amateur astronomers and clubs in the US with materials or equipment to donate.

To get this program going, we'd like to ask third world clubs and astronomical groups wishing to participate to contact us at the address below. Please let us know the following:

1) The name and address of your club and its officers.

2) The number of active members.

3) The equipment you need, listed in order of importance (i.e., eyepieces, mirror kits, books, etc.).

4) How you will use the equipment (for education, amateur observing, etc.).

5) The customs requirements of your country (we will give the equipment as a donation).

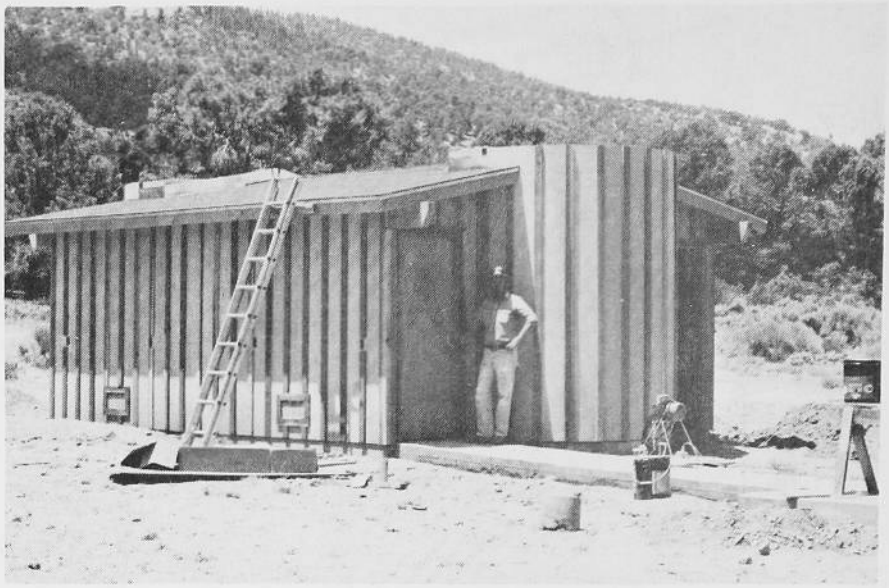
6) General background information about your club (activities, history, present facilities, meetings, etc.).

To do this, the WAA needs the help of American amateurs. We will accept donations of telescope parts and materials from anyone in the US who wishes to aid in this program. Write to me with a list of what you can donate, and I will let you know if it can be used in this program. I look forward to hearing from anyone interested.

Robert E. Schalck
Western Amateur Astronomers
25612 Belhaven Street
Hayward, CA 94545

RAS Gift to Camp Oakes

Dear Richard / I was wondering if anyone is keeping you informed on the progress of the observatory at Camp Oakes. As you remember from last year, the Riverside club was working with the camp to get a small structure built on the telescope field. Well, that snowballed into a beautiful double-dome observatory, with three large telescopes.



Celestron donated a 14-inch to the observatory, and, not to be outdone, Meade gave a 10-inch research grade telescope, and Coulter came up with one of their 17-inch units. Suddenly it was an embarrassment of riches! The camp directors started scouting around and came up with some substantial donations of money to purchase a pair of two-meter Observa-Domes and finish the building. One of the camp employees is a licensed contractor, so he enlarged the foundation to accommodate the new domes.

The final structure is beautiful. It is aligned roughly north-south, with a dome at each end. The center building section is large enough to hold small astronomy classes. One of the nicest features is the placement of several external outlets on the outside of the observatory building. At RTMC this year, there was plenty of electricity for people to use on the telescope field.

Our club is funding a 2-inch focuser and a Telrad finder for the Dobsonian, and one of our members will be going up there in a couple of weeks to install those items.

Richard Bean
Riverside Astronomical Society

Camp Oakes Gets Observatory

Dear Richard/ The Riverside Telescope Makers Conference introduced astronomy to Camp Oakes, and now Camp Oakes has its own astronomical observatory. When the Riverside Club donated a homemade 8″ reflector, we decided to build a small facility to house the instrument. Some of the members of the Riverside Club volunteered to set the concrete slab for a single dome structure which was to be of wood frame construction and have an 8′ diameter geodisic dome. Interest in the project picked up at the '84 RTMC, and several of the manufacturers who attended the three day event decided to contribute equipment to the unfinished observatory.

Celestron International donated a C14 Schmidt-Cassegrain along with many 1¼″ and 2″ occulars. Meade Instruments donated a 10-inch Newtonian scope with equatorial mount, right ascension drive, rotating ring, and 8x50 finder scope. Coulter Optics donated a 17.5-inch Dobsonian reflector telescope, and Parks Telescope Manufacturers donated a pair of 20x80 deep sky binoculars. Other representatives at the conference donated star charts and occulars ranging from 6mm to 50mm in both 1¼″ and 2″ sizes.

At this point, the observatory had to be enlarged, so additional concrete was poured to allow for a second dome base. The dome base cylinders are framed so that the interior half is a half-octagon and the exterior half is a semi-circle. The half octagon is framed by posts and beams and the semi-circle is framed with studs. This framing supports a plywood laminated ring to which the dome base ring is attached. Professionally made 2.5 meter domes were purchased from Observa-Dome of Jackson, Mississippi.

During the summer months, visitors used only the 17.5-inch Dobsonian from Coulter, as the mountings for the other scopes weren't ready. In September, work was resumed and isolated permanent concrete piers were placed within the framed cylinders. These piers now hold the permanent steel piers from Celestron and Meade on which the 14-inch and 10-inch scopes are mounted. An observation platform was constructed around each pier, with wood ladders extending from the concrete floor to the platform. The domes were assembled and raised by crane to be mounted on their respective base rings. Both domes are electrically driven with manual shutters, and the Celestron and Meade scopes were mounted and optically aligned. Currently, both telescopes are being fitted with accessory equipment to facilitate astrophotography.

Scott Petersen
Tom King
Camp Oakes YMCA
600 Long Beach Boulevard
Long Beach, CA 90802

Martian Crater Query

Dear Richard / Back in 1958 I was visiting old-time telescope builder John Mellish, in Escondido. He mentioned that during one particularly favorable Mars opposition (it was 1909, I think), he and E. E. Barnard were observing the planet with the 40-inch Yerkes refractor. According to Mellish, seeing approached perfection early one fine morning. Barnard, who was at the telescope, turned to Mellish and exclaimed, "There are craters on the Martian surface!" John took his turn at the eyepiece, and confirmed Barnard's discovery.

I forgot this conversation — until the Mariner photographs. If Barnard did note craters, this observation must be on record. Does anyone have information concerning it? Were drawings made?

Dick Nelson
3470 Travis Avenue
Simi Valley, CA 93063

Why No Tolles?

Dear Sir / I wonder if anyone could explain the demise of two excellent eyepiece types: Tolles and monocentric. These were described in the *Scientific American ATM Books*.

I have a ¼" focal length Tolles in use with my 16" Newtonian. I find it gives beautiful definition, and is as good, if not better, than my ¼" focal length orthoscopic, especially for planetary and lunar work. The only drawback is the rather small field of vision. These two types of eyepieces have to be among the best I have used, giving excellent eye-relief and freedom from ghosts, yet they appear to be no longer available. Why did they disappear? Can they be brought back?

Trevor Smith
129 Heanor Road
Smalley
Derbyshire
England
DE7 6DY

Apodizing: Edberg Replies

Dear Richard / Mark Trueblood's letter in TM#25 was a generally useful summary of apodizing. However, he is mistaken in suggesting that layered mesh screens approximate a Gaussian radial density gradient filter. "Close" only counts in throwing horseshoes. The opaque portions of mesh screen make all the difference in analyzing the Airy pattern for stepped density mesh apodizers versus true Gaussian apodizers, as I showed in TM#24.

A useful way of thinking about the effect of apodization is through the use of the Uncertainty Principle in quantum mechanics. The principle says one can't measure the position and momentum of a particle simultaneously to infinite accuracy. To get a feel for the principle, consider using a camera to measure the position and speed (a component of momentum) of a moving freight train. If you know the shutter speed of the camera and distance to the train tracks, you can measure the blur of the image and deduce the speed of the train, but the blur doesn't allow you to pinpoint the train's position precisely. On the other hand, if you use a faster shutter speed, the blur is minimized so you know where the train is, but you can't measure its speed.

Photons entering a telescope are confined to an area (position) determined by the aperture (analogous to the shutter speed). For small apertures the positions of the photons are better known, so they end up filling a larger area at the focal plane, making a larger Airy disk (equivalent to the train's speed). If the aperture is obstructed by a mesh screen, the entrance position of the photons are better known (they have to go through a small hole somewhere in the mesh), so the Uncertainty Principle requires that their momentum be more uncertain, such that they may end up in the spectra seen when mesh is used. Photons going through the reduced clear central aperture are confined to a smaller aperture than the full aperture of the telescope, so the Airy disk itself is also broader. These effects are illustrated by the Fourier Transform plots in my article. An aperture with a Gaussian or other smooth transmission profile does not confine the photons to an area smaller than the full aperture, so the Airy disk maintains its size but loses its rings.

Mesh screens in front of a telescope aperture just won't work. Modern physics has no method for beating the Uncertainty Principle. It is a fact of life that must be lived with. We astronomers are fortunate to be able to actually see this fundamental effect every time we look in a telescope.

Steve Edberg
California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109

Apodizing: Van Nuland Responds

Dear Richard / Since I precipitated the current discussions of apodizing screens, I hope you'll permit me to add another several cents' worth.

The greatest error in Steven Edberg's paper (TM#24) is the three-layer screen (openings of 25, 50, 75% of full aperture). This is totally wrong! It is obvious that he did not consult the literature. These are the screen series I've heard of, and the author and year of publication: 52, 78, 92% (Leonard 1954); 50, 70, 90% (Van Nuland 1982, suggested by Al Meyer); and 64, 72, 80, 88, 96% (Van Nuland after Carmack 1983). I asked Jeff Carmack about the 25-50-75 screen; he said that he had tried something like it and the result was a total disaster.

That a Gaussian transform characteristic results in the absence of diffraction rings is well-known in professional optical literature. Steve Greenberg (Livermore, CA) showed me some articles. Such analyses always limit themselves to perfect seeing and idealized screens, thus being of limited use in the present discussion, i.e., apodizing as a "seeing" filter.

The photographic experiments were of some interest, but are irrelevant to the topic since, as you have suggested, eye and brain processing is an important part of observing. I enjoyed Edberg's conclusions on this possibility. The hair dryer results in such immense turbulence that it seems utterly unrealistic as a simulation of poor seeing — nothing could help that!

I wonder if "Questar Effect" is responsible for some of his indifferent results — his 5-inch telescope is rather smaller than my 8-inch. Perhaps there is a dependency on aperture? Note that Art Leonard's Yolo has a small aperture. Probably not.

I will now pick up the events at Riverside/84 at the conclusion of Mr. Edberg's paper. Audience reaction to the conclusion ranged from surprise and disbelief to outrage. I was able to obtain the floor for a moment to quickly give directions to my telescope, and to "invite you all to come, see for yourselves, whether bumblebees can fly!"

I returned to the bus for supper and discussed apodizing techniques with Gene Lucas (Saguaro Astronomy Club, Phoenix, AZ). He suggested an irregular sawtooth applied to both mirror and secondary. This was done on a solar telescope years ago.

Early evening brought dozens of observers. Seeing was medium to poor. At 305x, I alternated between clear and apodized apertures for each observer. Not everyone liked the spectra, but all agreed that the view of Saturn was much better with the screen.

When the crowd thinned, Edberg remained. We tried my 5-layer screen, and the neutral-density filter that he recommended in the paper. I was startled to find how much the ND filter helped! Steve alternated between the ND, screen, and no filter. At last he stood up and said, "My ND filter is a help, but your screen is helping more. I thought I had this thing wrapped up — but obviously I have more work to do." He then examined my screens and took notes regarding their construction.

So there you have part of Mr. Edberg's experience that wasn't reported in TM#24. [In fairness to Steve, the paper was submitted to TM before it was presented at RTMC. — RB]

At Riverside/84, I also had the great pleasure to discuss apodizing with Art Leonard. I told him of my discovery of the "seeing filter" effect; he was entirely familiar with it! He had described it in the original article for *Scientific American* in 1954, but the article was shortened for publication and the seeing discussion was lost. He was very surprised at my report that the screen is of use on a Newtonian, and said that his work had indicated that it wouldn't help. This points out the difficulty of analyzing these things, when even Prof. Leonard came to a wrong conclusion. He later came to see my scope and agreed that Saturn was much better with the screen.

I'm happy to read of your experiments at Jeff Carmack's 17.5". He had made about 15 screens to arrive at the version you saw. I agree that every scope should have an apodizing screen!

Thank you for publishing Rodger Gordon's letter in TM#24. I wonder about the specifications of the "Metzger Glare Reduction Screen." Window screen construction? How many layers? Opening sizes? Perhaps someone has an old Edmund Scientific catalog.

Of course it is the "Perceived Image Quality" (PIQ) that is improved by the

screen. "Perceived image" is the only kind a visual observer can have. If I want to talk about what is happening up in front of my scope, I talk about turbulence, heat waves, or air motion. Some have been confused on this point, so perhaps a specific term would clarify the issue.

It is also my experience that the screen is of lesser use when the air is steadier. I find it useful even when the air is fairly steady — I try it whenever I'm seeking fine detail at high power.

So Edberg is annoyed by your suggestion that every scope should have an apodizing screen. Humpf. I'm annoyed by an analysis based on guesswork substituted for reading TM#18, and by grotesque experiments with a hair dryer. (I try to be objective, but that paper has so many holes that I keep losing my footing.)

Walter Scott Houston's report was most interesting. Art Leonard also declined to try the Yolo without the screen when I suggested it; in the dark I heard a definite scowl!

Does the f/ratio matter? Probably not. The stopped-down 17.5" is about f/13. The Yolo is very slow, yet Twinky's report differs from yours. I will carefully evaluate the screen on subtle details. Saturn, Jupiter, please hurry back!

My first experience with an astronomical telescope was in December, 1972, with the Sidewalk Astronomer's 24-inch. John Dobson and the SFSAs have been building their scopes for 20 years or so, yet these scopes were generally unknown outside the San Francisco Bay area until recently, with Kestner's articles in TM, when the hardcore hobbyist caught on. Even then, despite twenty years of John's efforts at popularizing astronomy and the Dobsonian, most amateur astronomers didn't take notice until a certain commercial builder saw TM#4 and TM#5, and shortly thereafter announced the Odyssey 1. There seems to be a lesson here. Commercial telescope companies: can you hear me?

Richard, please continue your coverage of apodizing. Perhaps we'll get a comprehensive analysis yet!

James H. Van Nuland
Calico Observatory
3509 Calico Avenue
San Jose, CA 95124

Apodizing: Art Leonard Enters the Fray

Dear Richard / The revival of interest in apodizing masks has prompted me to write this note. I hope that it will clarify some points that seem to have confused people.

The primary purpose of an apodizing mask is to increase the visibility of planetary details. These are details of low contrast and low contrast gradient. Since any planetary detail is in reality a mosaic of overlapping diffraction patterns formed on the retina of the observer's eye with each pattern corresponding to a separate point of light in the object, anything will sharpen the outline of any area on the planetary surface.

The Airy diffraction pattern (formed by one point source of light, like a star) consists of a central disk surrounded by a series of concentric bright rings. The first bright ring, which contains almost as much light as all the others put together, acts like a "fillet" between the central disk and the surrounding field, decreasing the sharpness of the edge of the central disk. If we could modify the distribution of light in the diffraction pattern so as to eliminate the rings — and especially the first bright ring — the outline of the central disk would be sharper and the outline of any area on the planetary surface would appear sharper.

To fulfill its primary purpose, any apodizing mask should reduce the total light in the first bright ring — and in the others too — relative to that in the central disk. The screen-type apodizing mask described in *Scientific American*, (June 1954, Vol.190, No.6, pp.102-105) is made from three layers of ordinary galvanized iron wire fly screen. The wire diameter is 0.0115-inches and the pitch is 18x13.3 wires per inch. The hole diameters, cut in the three screens, are 0.52, 0.76 and 0.88 times the aperture of the telescope.

These hole diameters were determined by extensive numerical calculations aimed at reducing to a minimum the total light in the first bright ring of the diffraction pattern. They apply to any unobstructed optical system, such as the refractor or the Yolo reflector. They do not apply to obstructed systems such as the Newtonian or Cassegrainian, or to any system having aberrations of appreciable magnitude.

Without an apodizing mask, an unobstructed optical system produces a diffraction pattern in which the ratio of the total light in the first bright ring to that in the central disk is 0.086. With the addition of the three-screen apodizing mask, this ratio is reduced to 0.016. This is more than a five-fold reduction in this detrimental feature of the Airy diffraction pattern.

Unfortunately, these numbers don't tell the whole story. No telescope is perfect. There will always be some small errors in the surface curves, and collimnation and seeing will never be perfect. These will degrade the performance of the apodized telescope differently from that of the unapodized instrument. A further and rather serious complication is that this apodizing mask reduces the brightness of the planetary disk, as seen in the eyepiece, to 0.47 of what it would be without the mask. This reduction in brightness amounts to 0.82 magnitude.

With a very bright planet, like Mars when it is near its perihelion, and a telescope of large aperture, the reduction in surface brightness may be beneficial for visual observation. On the other hand, with a planet of low surface brightness, like Saturn, and a telescope of small aperture, the reduction in surface brightness may be detrimental.

Another complication is that the apodizing mask produces an enlargement of the central disk of the diffraction pattern. With this mask, the enlargement amounts to 15%. This, very definitely, represents a loss in the resolving power of the telescope for all types of objects.

With an optical system having a central obstruction, an apodizing mask is unable to produce anywhere near as large a reduction in the brightness of the first bright ring of its diffraction pattern. The reason for this is that the mask, in cutting off some of the light that otherwise would be falling on the outer parts of the primary mirror, makes the central obstruction relatively larger. The detrimental effects from this relative enlargement of the central obstruction just about wipe out all the beneficial effects produced by the apodization.

A final complication is the fact that individual observers may differ quite a lot in their personal opinion of a given change in a planetary image. This all adds up to the conclusion that the addition of a screen-type apodizing mask to a given telescope may allow the observer to see more planetary detail, but it doesn't automatically do that.

One solution to the problem of providing the observer with better views of the planets might be to try to reduce the detrimental effects of the apodizing mask by going to a somewhat larger aperture. For example, suppose that the observer was thinking in terms of an 8" aperture. He could acquire a 10" instrument and then add a screen-type apodizing mask. This would give him a planetary disk with the image brightness of a 6.85" unapodized telescope and the resolving power of an 8.7". Since the effective aperture of a telescope with an apodizing mask is considerably less than its clear aperture, seeing will not degrade the image nearly as much. Thus, with a larger telescope and an apodizing mask, the observer may be able to see better planetary detail than he could with an unapodized telescope of any aperture.

Art Leonard
740 Elmwood Drive
Davis, CA 95615

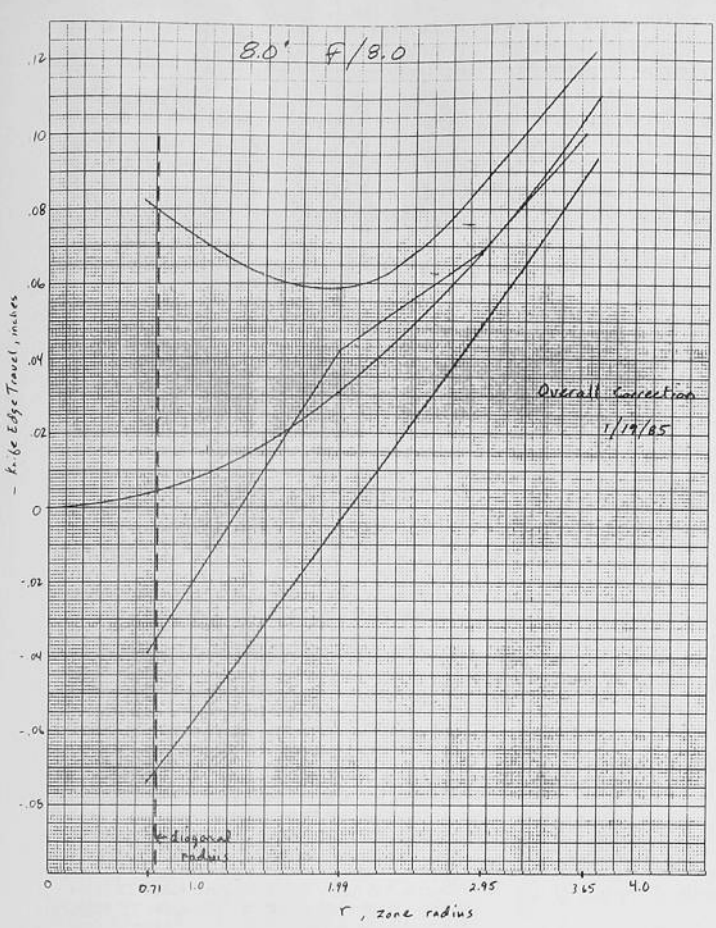
Apodizing: More from Art Leonard

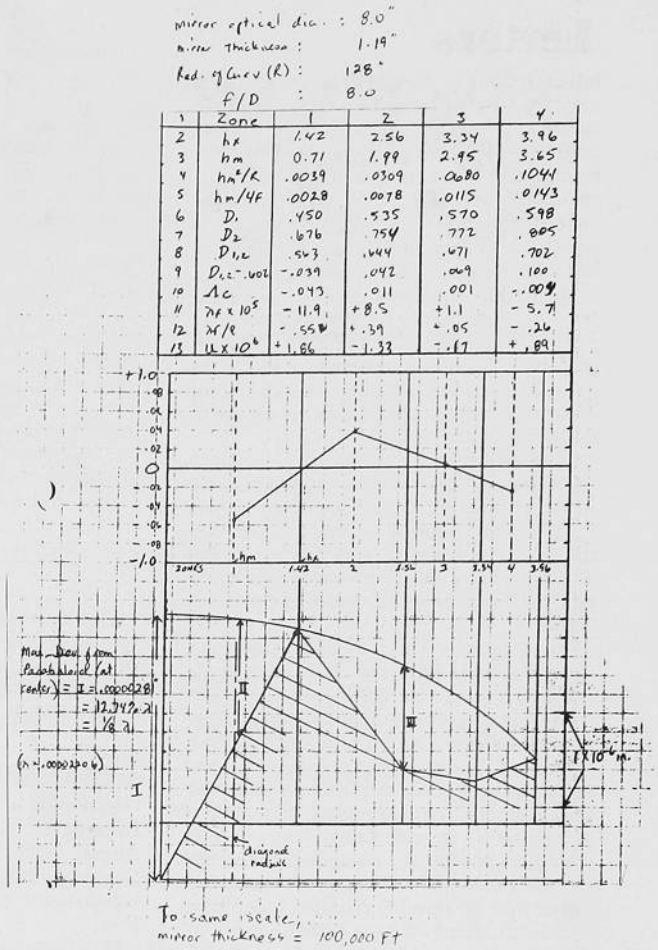
Dear Richard / Although I have known all along that my apodizing mask reduces the brightness of a planetary image and increases the diameter of the central disk of the diffraction pattern, I did not fully appreciate the magnitude of these effects until I completed my recent calculations.

I am afraid that in my original article on apodizing masks (*Scientific American*, June 1954), I may have misled some owners of Newtonian and Cassegrainian reflectors. In that article, I intimated that my design of apodizing mask, or some design fairly close to that, could improve very substantially the performance of telescopes having central obstructions. My original calculations showed fairly clearly that no design of apodizing mask would be able to produce much improvement in the diffraction pattern formed by an obstructed optical system. I should have stated that result in that article.

Some owners of obstructed reflectors have made and used screen-type apodizing masks and found them to be beneficial. I feel that in most of these applications the benefits have been due to the reduction in surface brightness of the planetary image rather than to the diffraction pattern modification. In those cases, a neutral filter in the eyepiece would accomplish the same result and it could be used on the Moon as well as on the planets.

Art Leonard
740 Elmwood Drive
Davis, CA 95616





Graphic Testing

Dear Richard / Thank you for your advice on the analysis of the mirror figure. The references you gave me on the Millies-LaCroix method and the Texereau analysis have made all the difference in my understanding of figuring and testing. I have now completed my first mirror (an 8" f/8) to an acceptable figure. I performed both the Millies-LaCroix and Texereau analysis I performed using my homemade Foucault tester — as you can see, they give the same result. I realize that the center of the mirror is a bit deep, but since the correction of the exposed or unobstructed area of the mirror is pretty good, I decided not to try and "raise" it. The edge looks good and I think I can live with a "bump" at zone 2. I sure hope it performs and I can't wait to try it!

All of the parts were made from scrap and the entire project took about five hours to complete. Thanks again for your help and for providing a forum in TM for us amateurs to share ideas and experiences, and in the process make new friends.

Gary D. Jensen
1125 S. Schaefer Street
Appleton, WI 54915

Overhead?

Dear Richard / Recently I acquired a rather interesting lens system, and am interested in exploiting it astronomically. It is a three-element lens system whose side proclaims "26 inch Transpaque f/4.4, Projection Optics, East Orange, N.J. (6" diameter)." I am afraid that it is too fast to use as a telescope, but would like your opinion. As I am a definite amateur (I don't even own a camera), please don't suggest anything too elaborate, though any ideas would be greatly appreciated.

Anthony Uchello
4512 Hastings Street
Metairie, LA 70006

— The lens in question sounds like an opaque projector lens. Such lenses were probably designed to cover a wide field with fairly low distortion. There is no problem with an f/ratio of 4.4, per se, but it probably isn't very sharp. It might not be too bad as a jumbo finder or low-power system for scanning. Have you tried viewing the image it forms with a low-power eyepiece?

Newtonian Diagonal Offsets

Dear Richard / I have been considering writing to you since receiving TM#22. I have been somewhat reluctant because I was afraid that the subject is commonly known or that it might appear inconsequential.

The equations by Ralph Dakin, summarized in TM#9, have been used by builders of fast systems for at least twenty years with great satisfaction. These provide the size and location of the diagonal for the very most efficient use of the light possible.

I had gone over the development of these equations and had considered them to be exact except for the curvature of field inherent in fast systems. I had also developed an algorithm giving the same results as the Dakin equations but also providing a method of computing the size of the diagonal for a centered system. David Stoltzman has recommended that the de-centered system not be used when constructing a system that is to be diffraction limited. This has to do with the asymmetry of the pattern produced by the de-centered system. But back to the Dakin equations . . .

D. Eric Allen, in his article "Updating Newtonian Collimation," states, at the bottom of page 4 in TM#22, that "the minor axis of the secondary can be measured directly from the drawing (see fig. 1) by drawing a line through point H out to either side of the light cone." This line represents a circular section of the cone. The minor axis of the ellipse is a line represented by the point H, that is, a chord of this circle — not a diameter.

It may be obvious to a geometer that his horizontal line through point H is the quantity given by the Dakin equations. It was not obvious to me. It did check to be the same in several numerical examples. I even tried carrying the results to sixteen significant figures and in every case Mr. Allen's statement was verified. I have since been able to verify this statement algebraically. What has gone wrong? If the diameter of the circle is equal to Dakin's minor axis, then the minor axis of the ellipse formed by the cone and the plane of the diagonal is then slightly smaller.

There is a fundamental assumption

Letters

inherent in the Dakin equations that is incorrect, but it leads to a trivial error in commonly used focal ratios. The present methods of forming diagonals cause the results to be correct in that they give the best minor axis available but they do not fit the cone of the light quite right. It would be possible to order a slightly smaller diagonal, but then the major axis would be too short.

The Dakin equations give the projected length of the major axis of the ellipse on a plane at right angles to the cone axis. The projecting lines are considered parallel to the axis. The problem is that Dakin's equations assume that the projection of the ellipse to the plane yields a circle.

Generally such a projection of an ellipse to a plane will yield another ellipse, a circle (which conforms to our prejudice in this case), or a line segment — depending on how the ellipse is oriented with respect to the projecting lines. The ellipse of interest in our systems projects to the plane as another ellipse.

When equations such as these have been in use for some time, the above statements can only arouse your skepticism. Let's take a fast system and see what happens. In the original article in *S&T*, Dakin used an f/1.5 system to illustrate the equations. Such a system will illustrate the error. In following the arithmetic, I would suggest that you use a computer or calculator with several memories so that the computed quantities can be retained to a consistent accuracy rather than re-entering rounded quantities.

The equations as you printed them in TM#9 are incorrect in that "an" is smaller than "af" in the drawing, while the equations give the reverse. To preserve the integrity of the drawing on page 11, let an = P/R; af = P/Q.

Dakin's equations give a value over 0.55 inch too large for the minor axis if the diagonal is to fit the cone of light.

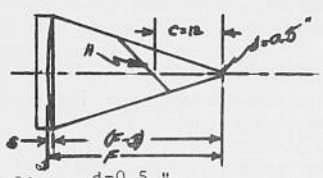
No one is going to build a 20" f/1.5 system with a 9.6" minor axis diagonal, and even if they did, the amount of light wasted by the improperly shaped diagonal is only 6.1%. In more normal systems, the diagonal is a few thousandths of an inch too wide at the minor axis and the percentage lost is more like 0.5%.

It appears that it would be possible to manufacture correctly shaped diagonals without considerable additional expense. The problem is in the metal sheath used to hold the diagonal in the spider. This sheath would have to be made for each order — too expensive except for those amateurs who want the very best. It does, at least, border on trivia, does it not?

Of course the purchaser would have to supply additional information to order a correctly shaped diagonal. He would need to specify the minor axis, focal ratio of the system, and the offset distance. In view of the insignificant savings in light, it is unlikely that the discovery of this error will influence trends in diagonal shapes.

Robert C. Follett
10331 Sheley Road
Independence, MO 64052

— And everybody thought that there was nothing new about Newtonians. It is humbling, indeed, to realize that in all these years, no one has noticed this before. Thank you for setting the record straight.



D=20" d=0.5 "
F=30"
D-d =19.5"
F-s= 30-20/16/1.5
= 29.166667
P=0.5x29.166667+12x19.5
=248.58333
Q=2x29.166667-19.5
=38.833333
R=2x29.166667+19.5
=77.833333
Offset =(P/Q-P/R)/2
=1.6037487
Minor Axis=P/Q+P/R
=9.5950776 (Dakin's value)
Dia. of Cone at Pt. H=0.5+13.6037487x19.5/29.166667
=9.5950776
Radius of cone =4.7975388
Equation of cir. Sec: $x^2+y^2 = (4.7975388)^2$
The offset x= 1.6037487
y=4.5215449
Actual Minor axis of ellipse =2y=9.0430899

Lightening the Tube

Gentlemen: In his review of the Odyssey II Dobsonian telescope in ASTRONOMY, August 1985, David Eicher says that the Odyssey's tube is a shortcoming because it weighs over 200 pounds. Certainly this is true.

However, I don't have problems with my Odyssey II, Polifemo, because my telescope's tube only weighs 20 pounds. This tube is made of acrylic resin. Two small children can carry it without help. The tube is, as you can see from the accompanying photographs, detachable.

Jose Velez
Tezozomoc 187
Col. Ciudad del Sol
45050 Guadalajara
Jelisco, Mexico

— Wasn't Poliphemus the one-eye giant *who kept Ulysses and his men captive? Clever.*

Mirror Source

Dear Richard/ TM readers thinking of building Tom Dey's binocular finder in TM#15 may be interested in the front-surface mirrors (their stock #TM23K507) available from:

H & R Corporation
401 E. Erie Avenue
Philadelphia, PA 19134.

The mirrors are the right size for 7x50 binoculars, and seem to work very well. Since they are very thin, careful mounting is necessary. I used 3 spots of aquarium cement, one at 25% and two at 75% of the length.

Franklin A. Dobson
1068 Vallejo Circle
Costa Mesa, CA 92626

■

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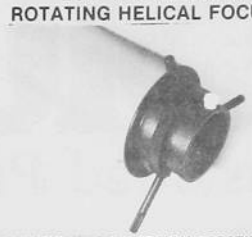

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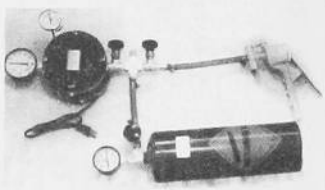

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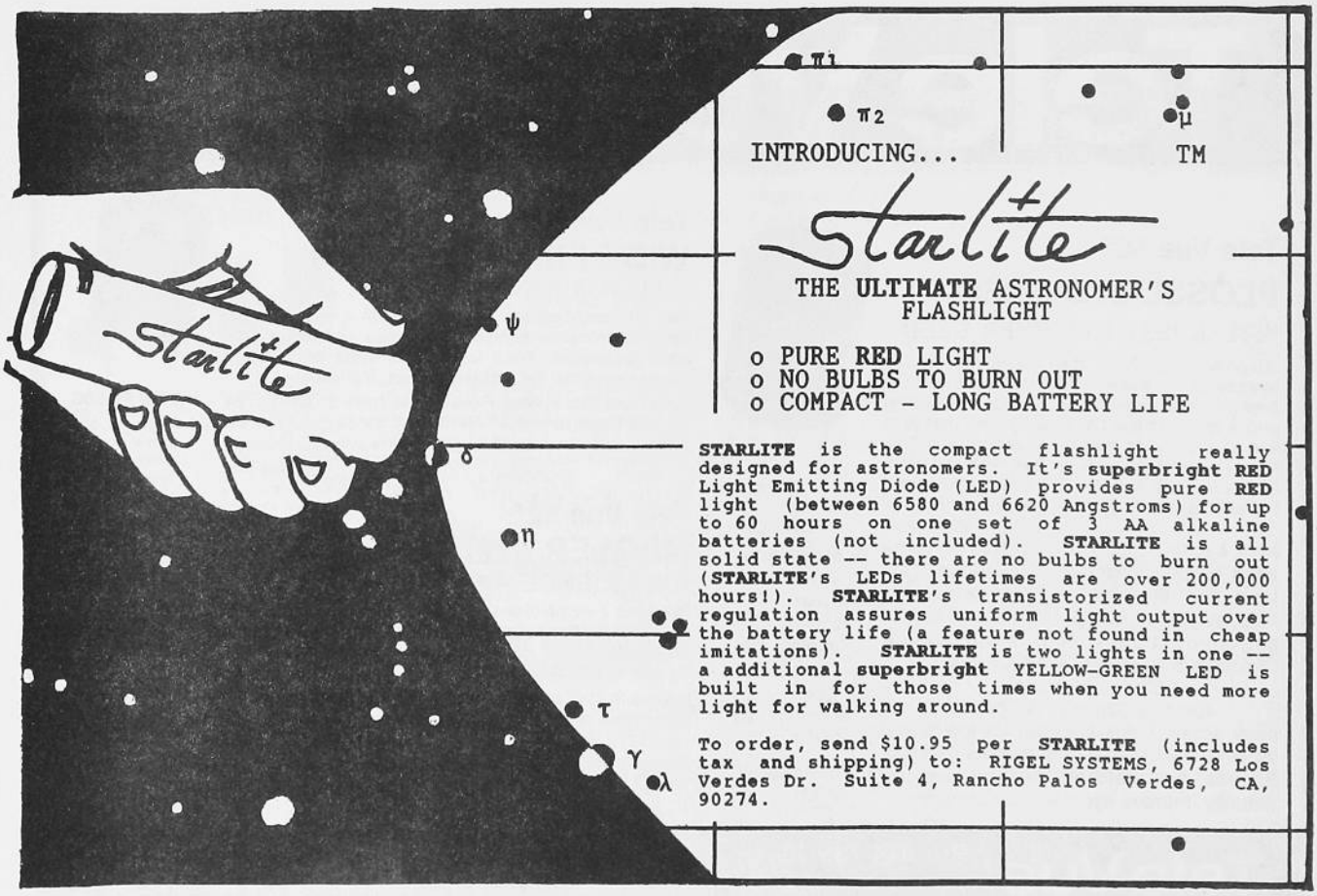

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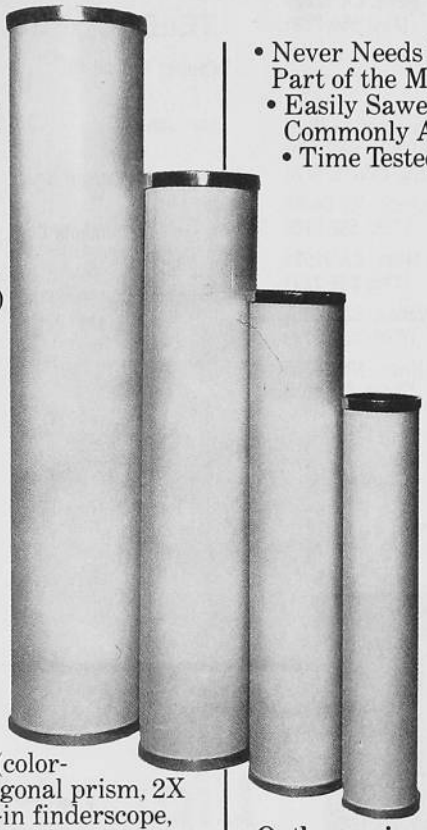

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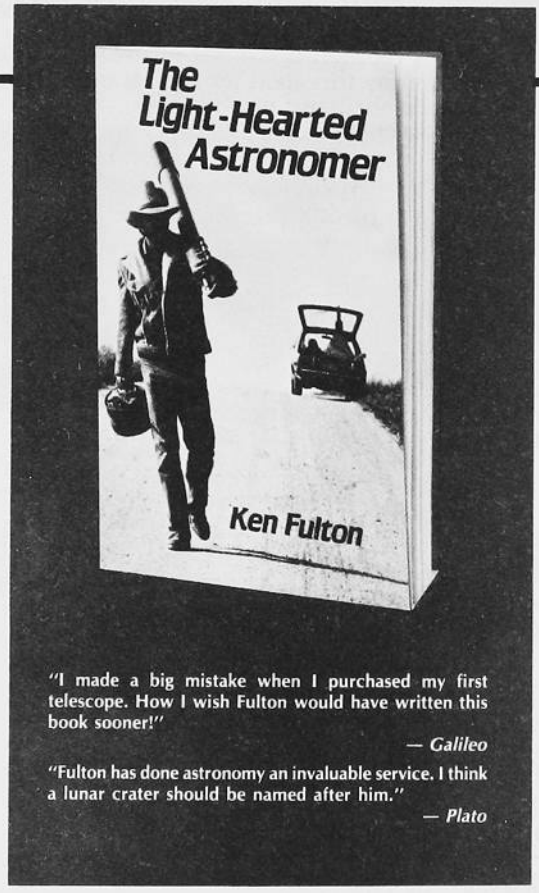

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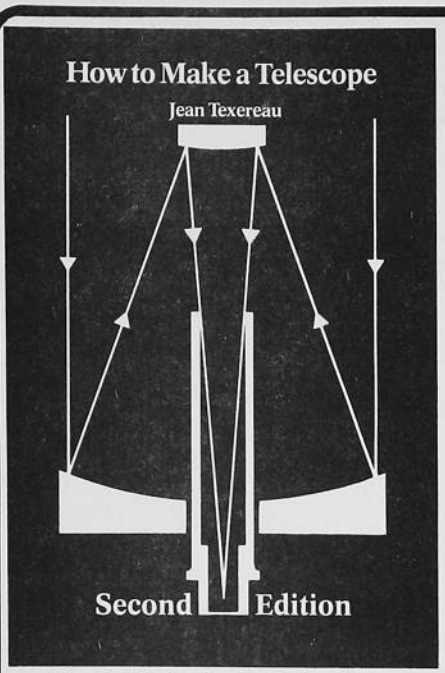

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ACKNOWLEDGMENTS
FOREWORD to the Second English Edition, Richard Berry
FOREWORD to the First English Edition, Albert G. Ingalls
FOREWORD to the 1951 French Edition, Andre Couder
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From the Foreword to the First Edition
Albert G. Ingalls
Editor: *Amateur Telescope Making I, II, and III.*
Scientific American magazine

I owe a lot to the first edition. My first mirror, begun when I was 13 years old, was a trial and error effort; and indeed, the whole project might have ended in failure had a local telescope maker not taken the time to show me how to parabolize it. My second mirror was figured to a fine paraboloid; finding Jean Texereau's book made all the difference. Since those first mirrors, I have gone on to make a dozen more, taught mirror-making to others and built many telescopes, but I still turn to Texereau.

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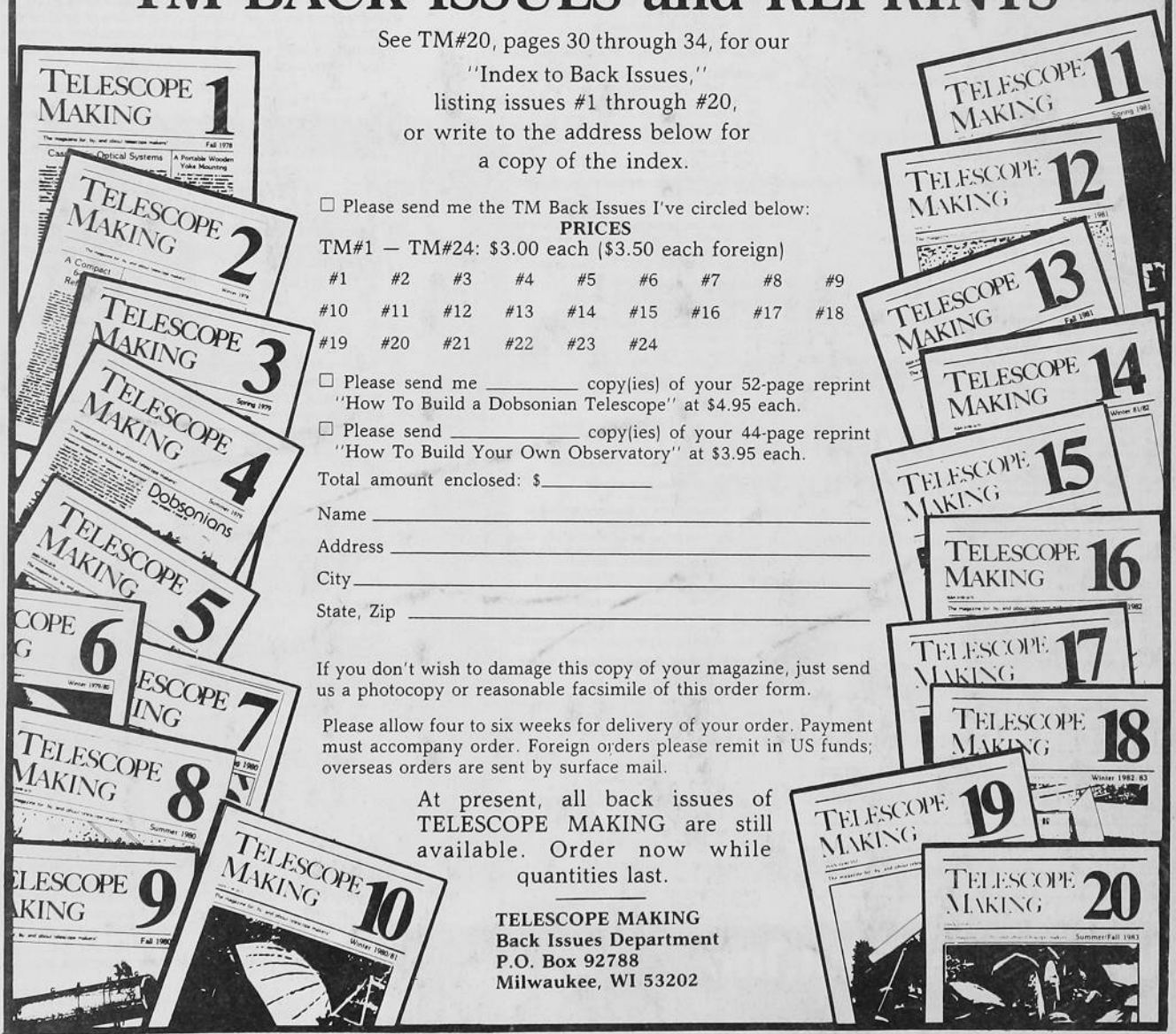

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